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THEORETICAL CALCULATIONS OF THE DETONATION OF A 1,000-POUND SPHERE OF TNT AT 15 FEET ABOVE GROUND LEVEL

Charles E. Needham
Edmund A. Nawrocki, Captain, USAF
William A. Whitaker, Captain, USAF

TECHNICAL REPORT NO. AFWL-TR-66-128
October 1966

AIR FORCE WEAPONS LABORATORY
Research and Technology Division
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This research was performed under Program Element 7.60.06.01.02, Project 5710, Task 571001, and was funded by the Defense Atomic Support Agency (DASA).

Inclusive dates of research were 10 July 1966 to 10 September 1966. The report was submitted 4 October 1966 by the AFWL Project Officer, Mr. Charles E. Needham (WLRTH).

This report has been reviewed and is approved.

CHARLES E. NEEDHAM
Project Officer

RALPH H. PENNINGTON
Colonel, USAF
Chief, Theoretical Branch

CLAUDE K. STAMBAUGH
Colonel, USAF
Acting Chief, Research Division

ABSTRACT

The results of a theoretical calculation of the detonation of 1,000 pounds of TNT (loading density 1.608 gms/cc) are presented. The charge was detonated 15 feet above ground with an ambient pressure of 12.6 psi and an ambient temperature of appproximately 100°F. The calculation started with the burning of the TNT and was carried to 115 milliseconds. The calculation clearly shows Mach stem formation, triple point path, and flow field. The theoretical calculation agrees well with experimental data obtained from a test conducted by AFWL at Holloman AFB.

CONTENTS

ILLUSTRATIONS

TABLES

SECTION I

INTRODUCTION

In recent years much effort has been expended in attempts to experimentally measure the parameters of the Mach stem and associated phenomena. Most recently this was done in Operation Distant Plain* (reference 1).

In support of this operation the Air Force Weapons Laboratory was requested by the Defense Atomic Support Agency to make predictions of air blast parameters and associated two-dimensional effects to assist in pre-shot planning. These predictions are based on theoretical calculations made by large hydrodynamic computer codes, which begin from first principles rather than from scaling laws or empirical models.

After the theoretical calculations of Distant Plain phenomenology were completed, Colonel Ralph Pennington learned of a similar experiment just completed at Holloman AFB, New Mexico. In this experiment a 1,000-pound spherical charge of TNT was detonated and extremely fine field data were obtained. Therefore Colonel Pennington suggested a calculation be made of the Holloman shot for purposes of comparing theoretical calculations and experimental data.

Presented in this report are the results of and comparison between the theoretical calculations and the experimental data of the Holloman experiment.

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*At this time, no experimental data have been received from the Distant Plain series.

SECTION II

THE ONE-DIMENSIONAL CALCULATION

The one-dimensional calculation was made using a modified version of the AFWL SAP Code on the AFWL CDC-6600 computer. SAP is a one-dimensional, spherically symmetric, Lagrangian hydrodynamic computer code. It has been modified to include two materials and a burn routine.

For this calculation 800 zones were given equal delta R's (where R is the radius) of 0.16 cm. The first 254 zones were given a density of 1.608 gm/cm^3 and were flagged as TNT zones. These conditions resulted in a charge weight of 996 pounds, the same weight as that used in the experiment. The remaining zones were given ambient atmospheric conditions.

Although a hydrodynamically stable real atmosphere is a standard part of the SAP program, it was not possible to make use of this because of the unusual conditions found at Holloman AFB. The low pressure and high temperature of the air at Holloman correspond--through the SAP equation of state for air--to a density which is far lower than that in a normal sea-level-based atmosphere for the same altitude (7000 feet). A stable atmosphere, which coincided with the 12.6 psi and 100°F conditions on the day of the experiment, was developed.

To calculate the burning of TNT, two input numbers were required: (1) the velocity of the detonation wave (a constant determined by density) in TNT, (2) the energy released per gram of TNT upon burning. The equation of state for TNT was also required.

The detonation velocity used for this run was 6.98×10^5 cm/sec, and the energy released was 4.26×10^{10} ergs/gm. The equation of state used was the LSZK formulation for TNT. (References 2 and 3.) For a detailed description of the SAP code and of the burn routine see reference 4.

The detonation wave reached the surface of the TNT at 0.058 msec with a peak pressure of 1.75×10^{11} dynes/cm^2. Figure 1 shows the wave profile just before it reaches the TNT surface, and figure 2 shows the profile after the front breaks the surface of the TNT. In this figure the velocity is seen to increase in this free expansion phase. The pressure and density curves have the same shape that they did prior to free expansion with the exception of the peak, which has been

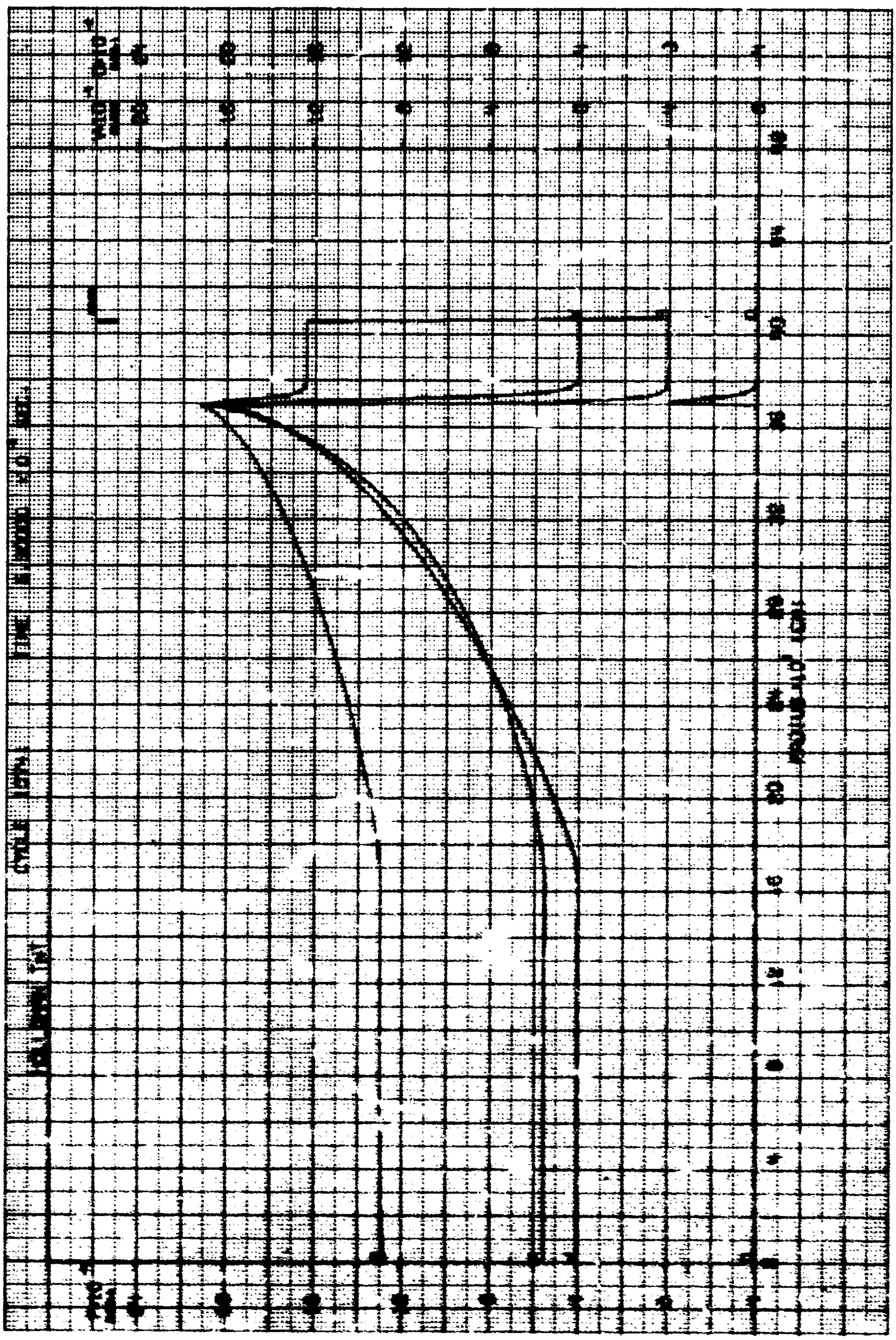

Figure 1. Profiles of Hydrodynamic Variables as a Function of Distance For the One-dimensional Calculation at Selected Times.

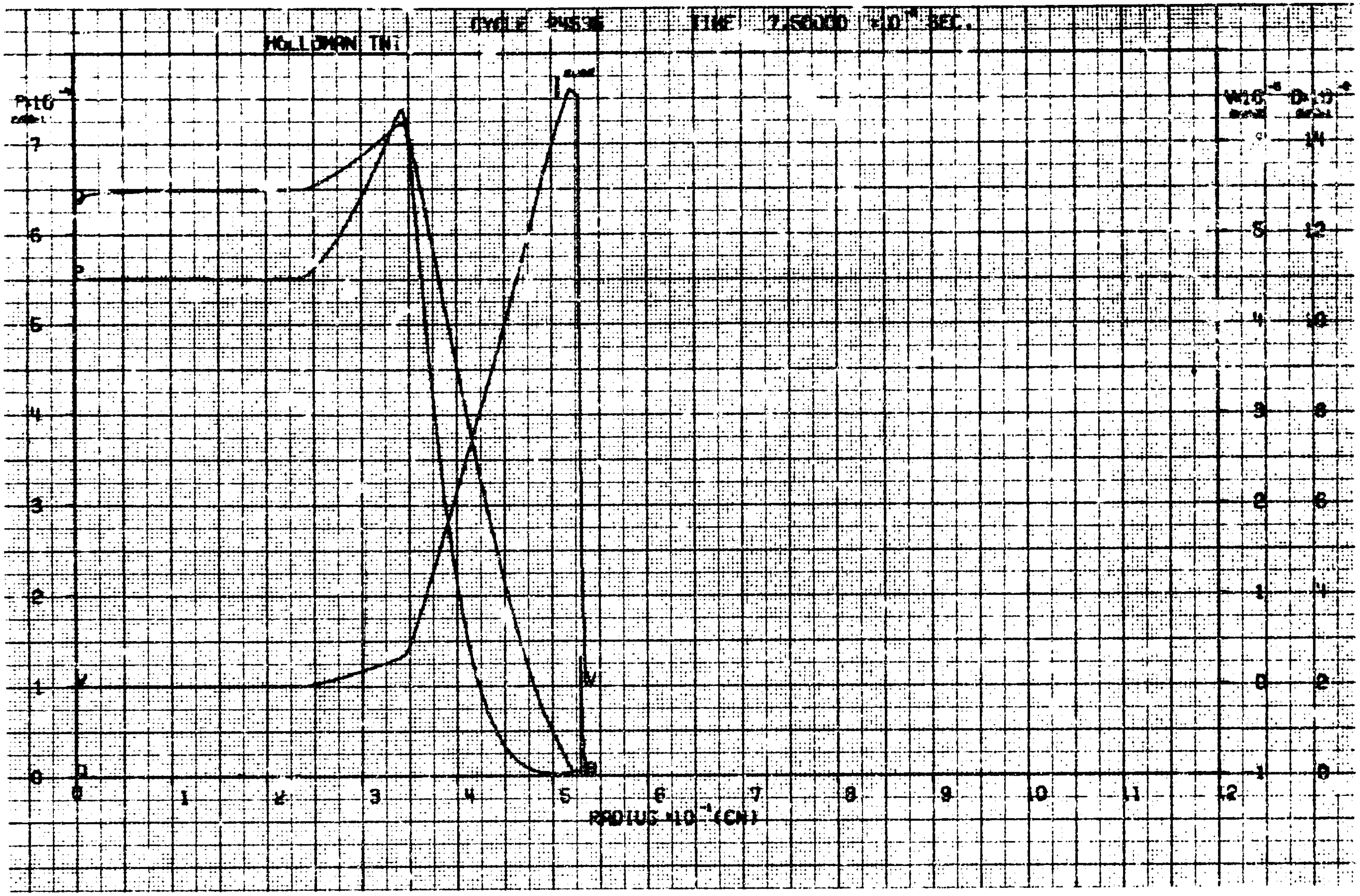

Figure 2. Profiles of Hydrodynamic Variables as a Function of Distance For the One-dimensional Calculation at Selected Times.

eaten away by the rarefaction wave. The free expansion cools the TNT and the TNT behaves like a cold piston compressing the low density air ahead of it. Figure 3 shows the profiles just before the rarefaction wave reaches the center.

Figure 4 shows the profile at the beginning of the two-dimensional calculation. Notice that all velocities are positive and that a sharp velocity gradient has developed just inside the TNT-Air interface.

The one-dimensional calculation was continued beyond the beginning of the two-dimensional calculation to compare the two runs and to show more clearly the two-dimensional effects. Figure 5 shows the profile as a shock moves inward from the TNT surface to the center. This shock is reflected from the center and forms a second outgoing shock. Many more small shocks are formed and follow in a similar manner. Following the reflected shocks in the one-dimensional case is interesting but probably of little value since two-dimensional effects are much more important.

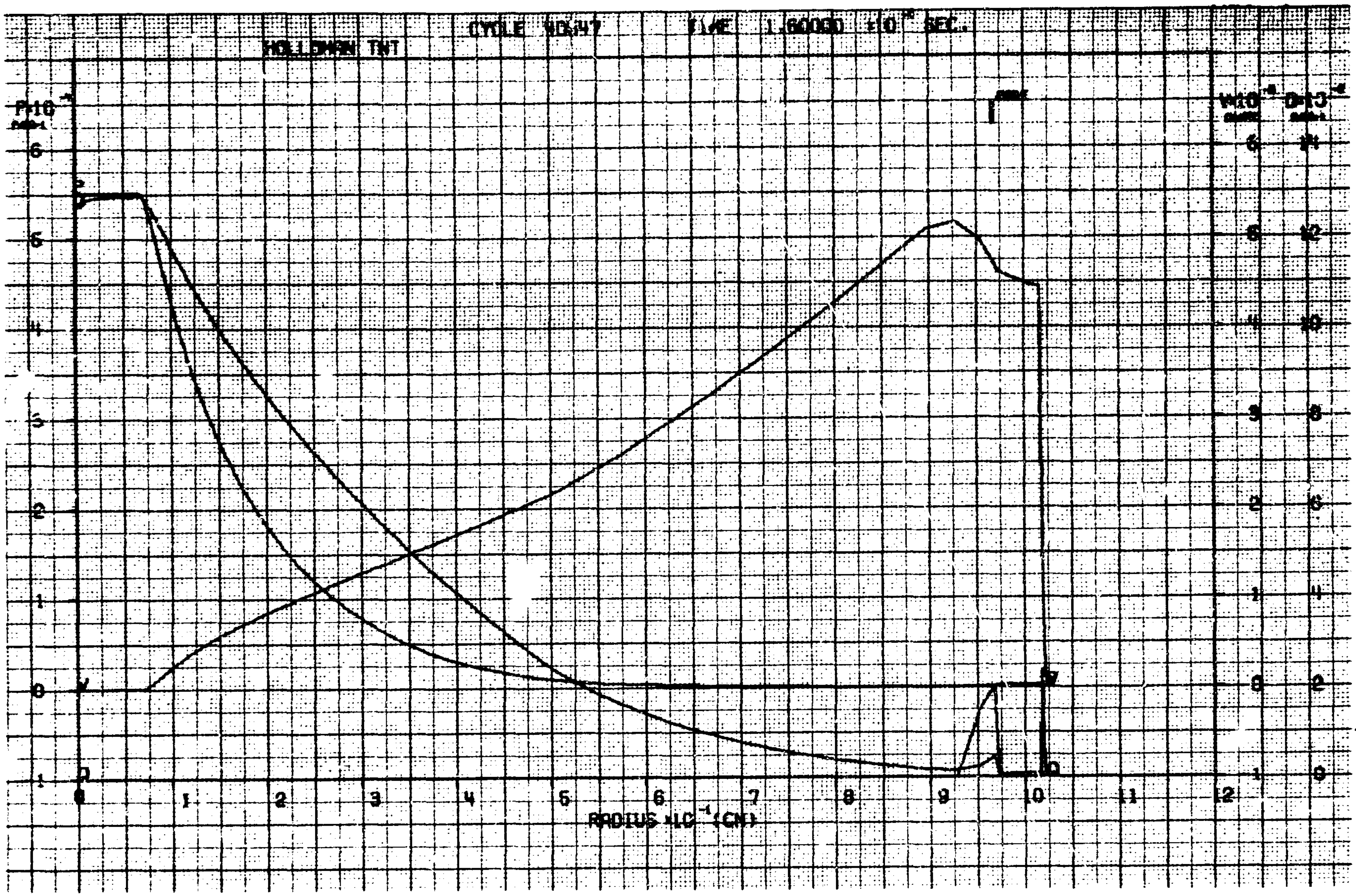

Figure 3. Profiles of Hydrodynamic Variables as a Function of Distance For the One-dimensional Calculation at Selected Times.

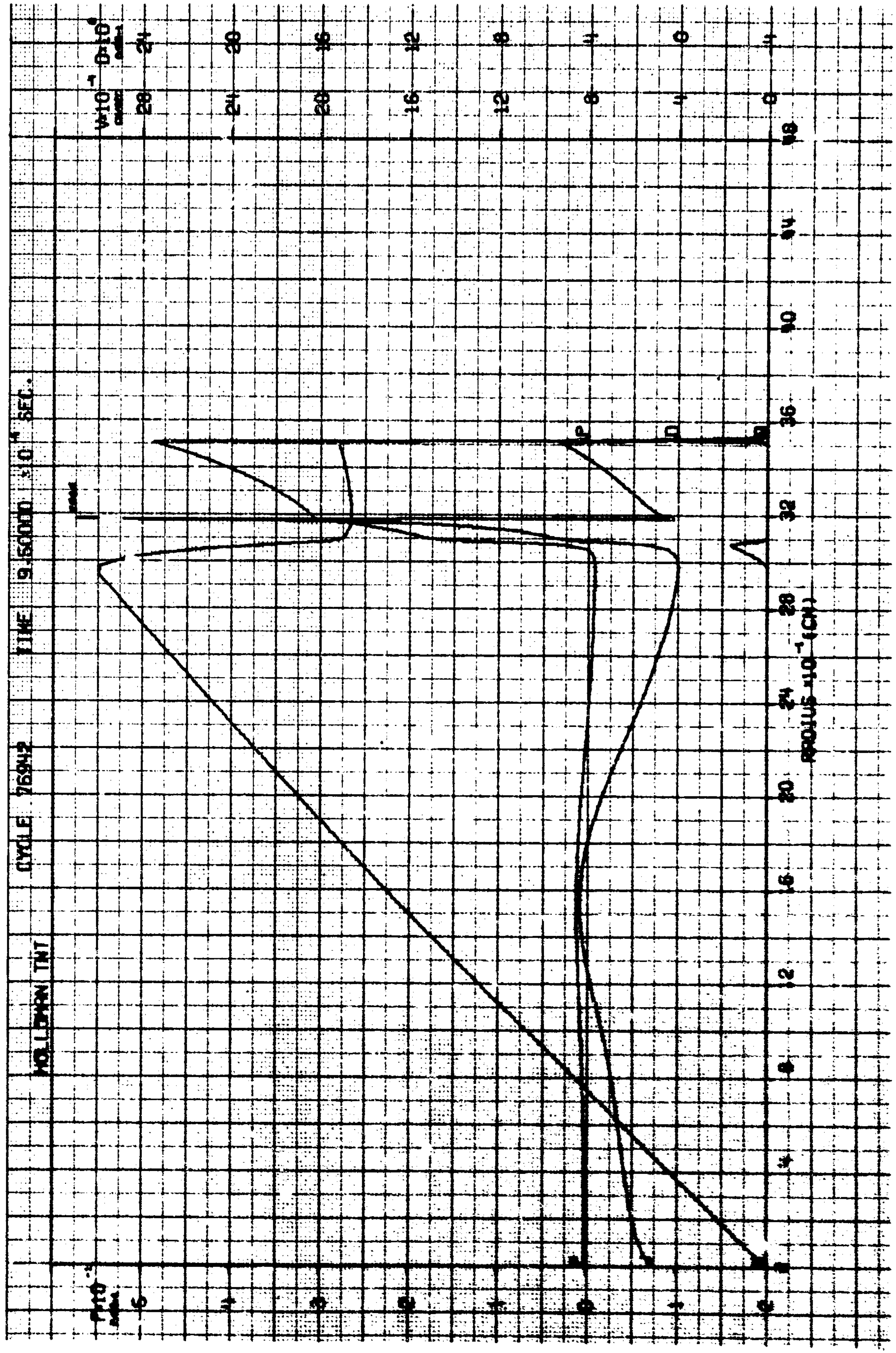

Figure 4. Profiles of Hydrodynamic Variables as a Function of Distance For the One-dimensional Calculation at Selected Times.

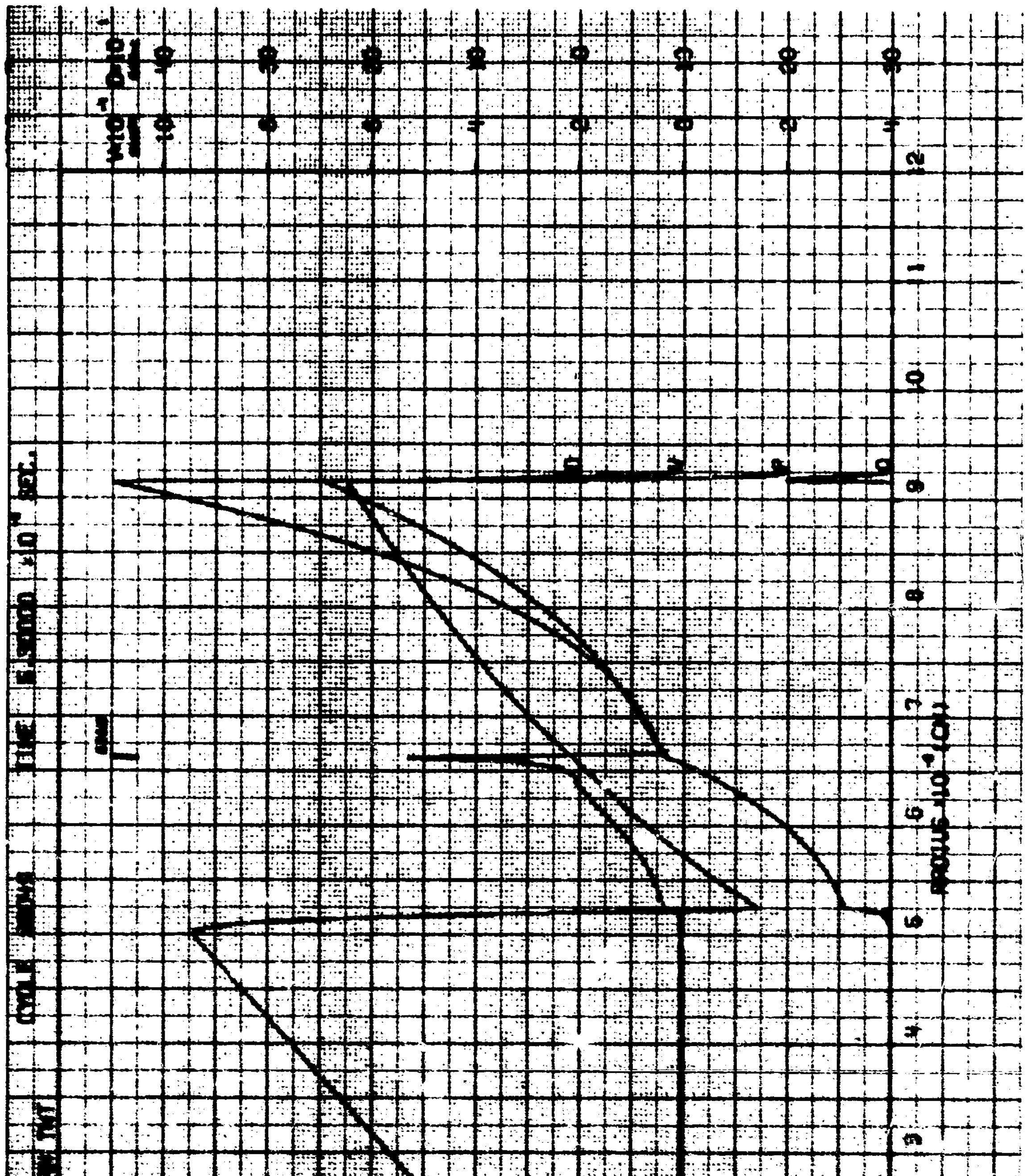

Figure 5. Profiles of Hydrodynamic Variables as a Function of Distance For the One-dimensional Calculation at Selected Times.

SECTION III

THE TWO-DIMENSIONAL CALCULATION

The two-dimensional calculation was made using the AFWL SHELL-OIL code on a CDC-6600 computer. SHELL-OIL is a two dimensional, pure Eulerian, axially symmetric, hydrodynamic code. SHELL is a one-material code; that is, all material in the problem is assumed to have the same equation of state. For this calculation the Doan-Nickel equation of state for air (reference 5), an empirical fit to Hilsenrath's data, was used. (For a detailed discussion of SHELL see reference 4.)

Some question arises as to the validity of treating TNT as air. At the time when the two-dimensional calculation was started (0.95 msec), the TNT had expanded to such an extent that it had a density comparable to that of the ambient air. This fact, combined with the relatively low temperature found throughout the TNT at this time, insures the validity of this assumption. To confirm this, a short one-dimensional calculation (SAP) was made using the air equation of state for all material. Differences between the two one-dimensional runs were on the order of 1 percent.

A minor modification was made in the SHELL program to allow monitoring at fixed points in the grid. Nineteen such points (test stations) were used in this calculation. The first eleven test stations were chosen to coincide with the experimental instrumentation stations. The twelfth through nineteenth test stations were placed at burst height at increasing radii. A complete list of station positions is given in table I.

The plots from these stations show the initial shock, the shock reflected from the ground, the second shock from the center, and the passage of the triple point past burst height. Figure 6 shows the triple point path relative to the test stations.

Included in this calculation were 801 trace particles. These particles follow the fluid motion but do not influence the hydrodynamics in any way. Initially, these particles were placed on the TNT-Air interface at equal intervals. The movement of these particles represents the motion of the interface as a function of time and appears as a heavy line on the contour and velocity vector plots in Appendix I.

Table I

TEST STATION POSITIONS

Station	Ground Range		Height	
	(Meters)	Feet	(Meters)	Feet
1	(10.67)	35.0	(1)	3.28
2	(12.8)	42.0	(1)	3.28
3	(15.5)	51.0	(1)	3.28
4	(17.98)	59.0	(1)	3.28
5	(19.5)	64.0	(1)	3.28
6	(21.03)	69.0	(1)	3.28
7	(23.47)	77.0	(1)	3.28
8	(26.52)	87.0	(1)	3.28
9	(29.26)	96.0	(1)	3.28
10	(31.39)	103.0	(1)	3.28
11	(35.35)	116.0	(1)	3.28
12	(5.0)	16.40	(4.57)	15.0
13	(6.0)	19.69	(4.57)	15.0
14	(8.0)	26.25	(4.57)	15.0
15	(10.0)	32.80	(4.57)	15.0
16	(12.0)	39.37	(4.57)	15.0
17	(15.0)	49.21	(4.57)	15.0
18	(20.0)	65.62	(4.57)	15.0
19	(25.0)	82.02	(4.57)	15.0

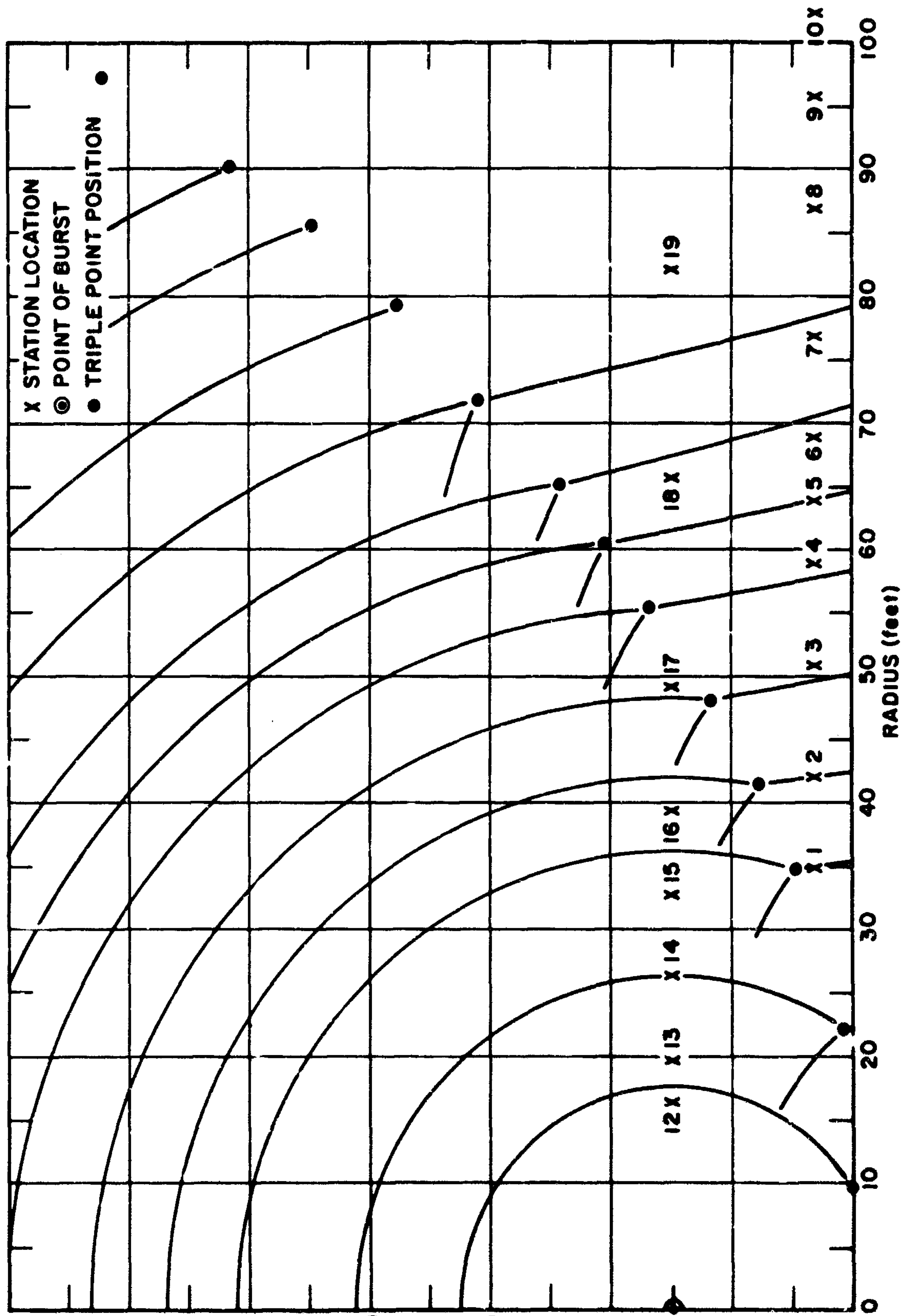

Figure 6. . Triple Point Path.

Initially the SHELL mesh was a rectangle 142 zones in the radial (r) direction by 156 zones in the vertical (z) direction, in which each zone was 6 cm square. The entire rectangle has cylindrical symmetry about the verticle line r = 0. A sphere of radius 3.5515 m centered at r = 0, z = 4.572 m was generated. Into this sphere were placed the hydrodynamic variables as a function of radius, as calculated by SAP at 0.95 msec. Outside of this sphere the same ambient atmospheric conditions were generated as had been used previously in SAP. The bottom boundary, z = 0, was made reflective, and the calculations was begun.

As the calculation progressed and the shock expanded, an automatic rezone enlarged the grid by approximately 6-1/2 percent in linear extent each time the shock reached the edge (top or side) of the grid.

The small periodic jumps in the overpressure versus time curves and the associated plots in Appendixes I and II were due to this rezoning. The jumps occurred when a station, fixed in space, changed its position relative to the mesh by an amount sufficient for the station to occupy a different zone. This condition, in effect, changed the position of the station by one zone dimension. The jumps could have been smoothed very easily but would have only served aesthetic purposes.

In the discussion of the one-dimensional calculation, a shock was shown converging on the center of burst and forming a second outgoing shock. The radius of the outer shock was approximately 30 feet at this time. This means that the outer shock reached the ground and reflected to the center of burst before the converging shock had time to reach the center. Consequently, the convergence occurred at a point higher than the original center and also earlier than in the one-dimensional case. However, the second shock having been reflected from this new center, reached the ground at the same time in both calculations. It is this second shock that appears as the smaller peak on the overpressure versus time curves for stations 1-11. (Appendix II.)

SECTION IV

COMPARISON OF EXPERIMENT AND CALCULATION

The experiment was conducted by AFWL in conjunction with the Blast Environment Development portion of the Rocket Sled Blast Simulation Program at Holloman AFB, New Mexico.

A 996-pound sphere of TNT was detonated 15 feet above ground level. The data collected include the high-speed photographs and pressure-time histories at the first 11 stations listed in table I. All experimental instrumentation was below the triple point and thus in the Mach stem.

The analog data tapes were digitized, and plots were made at the Kirtland AFB Data Reduction Center. Arrival times and positive phase durations were read directly from the digitized tapes, but no direct measurements of overpressure impulse were made. The impulses given on the data graphs were computed by numerical integration of the overpressure time curves. Because of instrument noise, these impulses had oscillations of about 20 percent and have been included only for completeness.

Figure 7 shows the peak overpressure, both experimental and calculated, as a function of ground range. The overpressure impulse is that calculated by SHELL. The maximum difference between experimental and calculated overpressure is approximately 18 percent. The experimental curve oscillates about the calculated curve and the resulting differences have been interpreted as experimental error. Table II contains the exact values for overpressure and overpressure impulse data. Figure 8 shows the arrival time and positive phase duration of the main shock, both experimental and calculated, as a function of ground range. Again, the experimental data oscillate about the calculated curve with a maximum deviation of 7 percent in arrival time and of 12 percent in positive phase duration. The difference in arrival time is within experimental error. The larger percentage error in positive phase duration has been attributed to the compounded error in arrival time and to the electronic noise in the overpressure measurements. The noise present caused the overpressure to appear negative in some instances before and others after the negative phase had actually started.

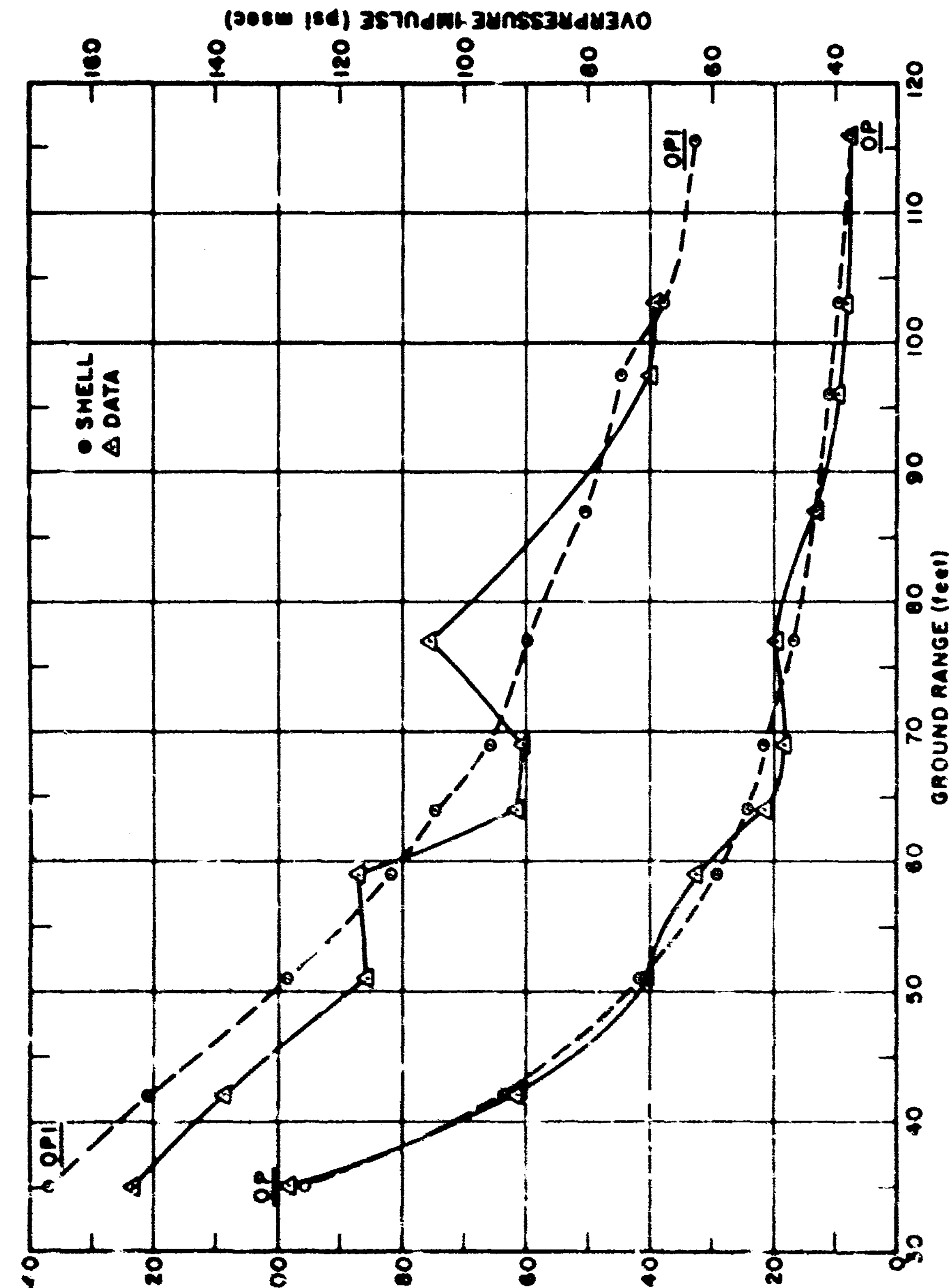

Figure 7. Overpressure and Overpressure Impulse vs. Ground Range.

Table II

OVERPRESSURE AND OVERPRESSURE IMPULSE DATA

Station	Distance (feet)	Data		Shell	
		OP	OPI	OP	OPI
1	35	98.2	153.4	95.8	167.0
2	42	61.5	138.8	63.8	151.0
3	51	40.7	115.9	41.9	128.4
4	59	32.5	117.2	29.2	111.9
5	64	21.3	91.4	24.2	104.8
6	69	18.2	90.4	20.8	96.0
7	77	19.8	105.5	16.9	89.8
8	87	13.1	57.9	13.2	80.2
9	96	9.5	69.9	11.0	74.5
10	103	8.1	69.0	9.6	67.7
11	116	7.4	38.0	7.7	62.8

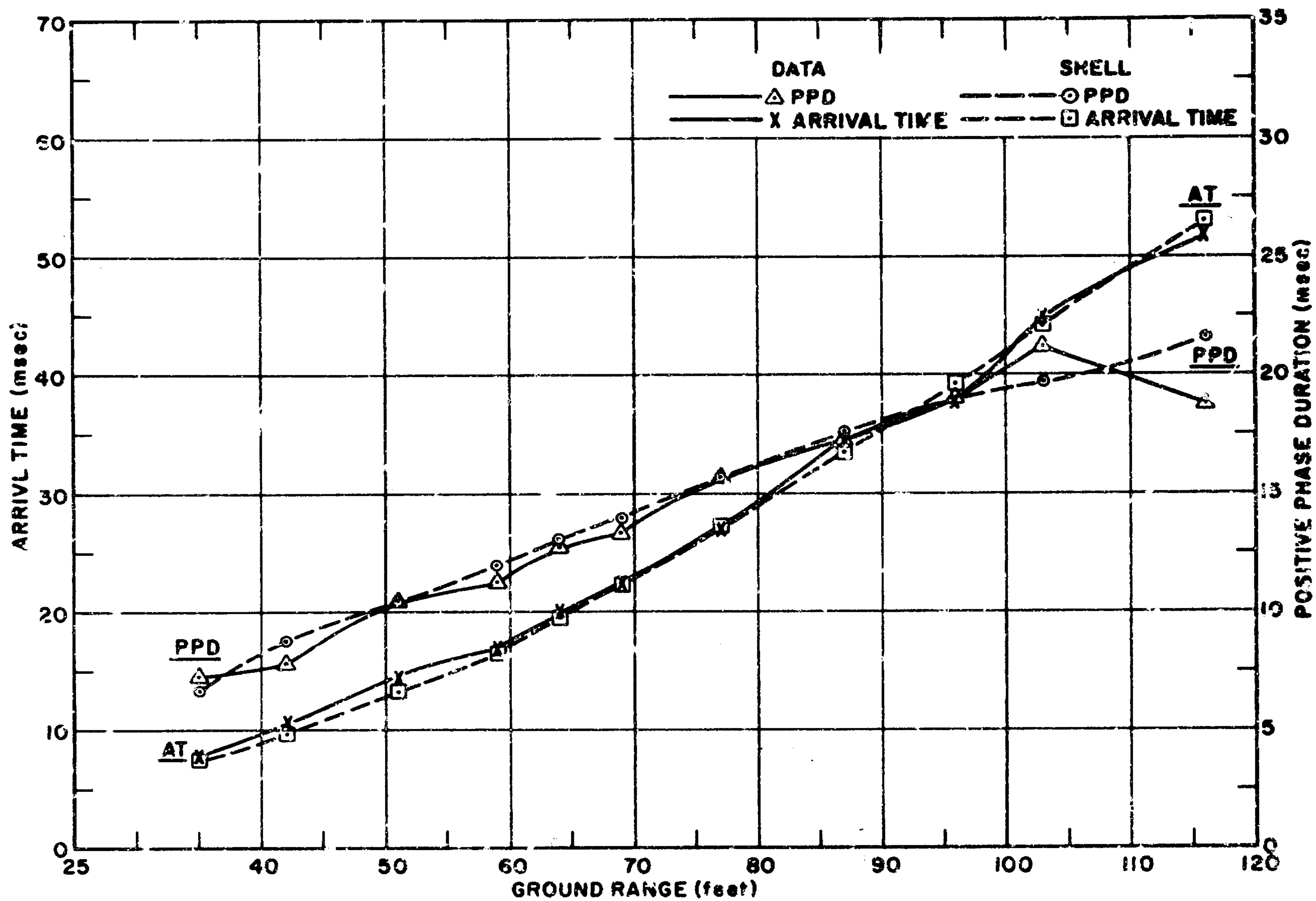

Figure 8. Arrival Time and Positive Phase Duration vs. Ground Range.

The depression at the back of the shock on the experimental curves was caused by instrument design and should be ignored. This depression, however, contributed, by lowering the impulses, to the previously described error, in the experimental overpressure impulse calculation. Figure 9 shows dynamic pressure and dynamic pressure impulse versus ground range.

The greatest discrepancy between the SHELL calculation and the experiment is due to the second shock arrival time. The calculation indicates a second shock arrival time about 8 milliseconds greater than that measured experimentally at the first station, and this difference in time increases with distance. (Compare the experimental and theoretical graphs in Appendix II.) At this time, no satisfactory explanation has been made for the difference, but several possibilities are being investigated.

The minimum overpressure before second shock arrival and the peak overpressure of the second shock agree within experimental error. This makes the discrepancy in second shock arrival time even more difficult to understand and explain.

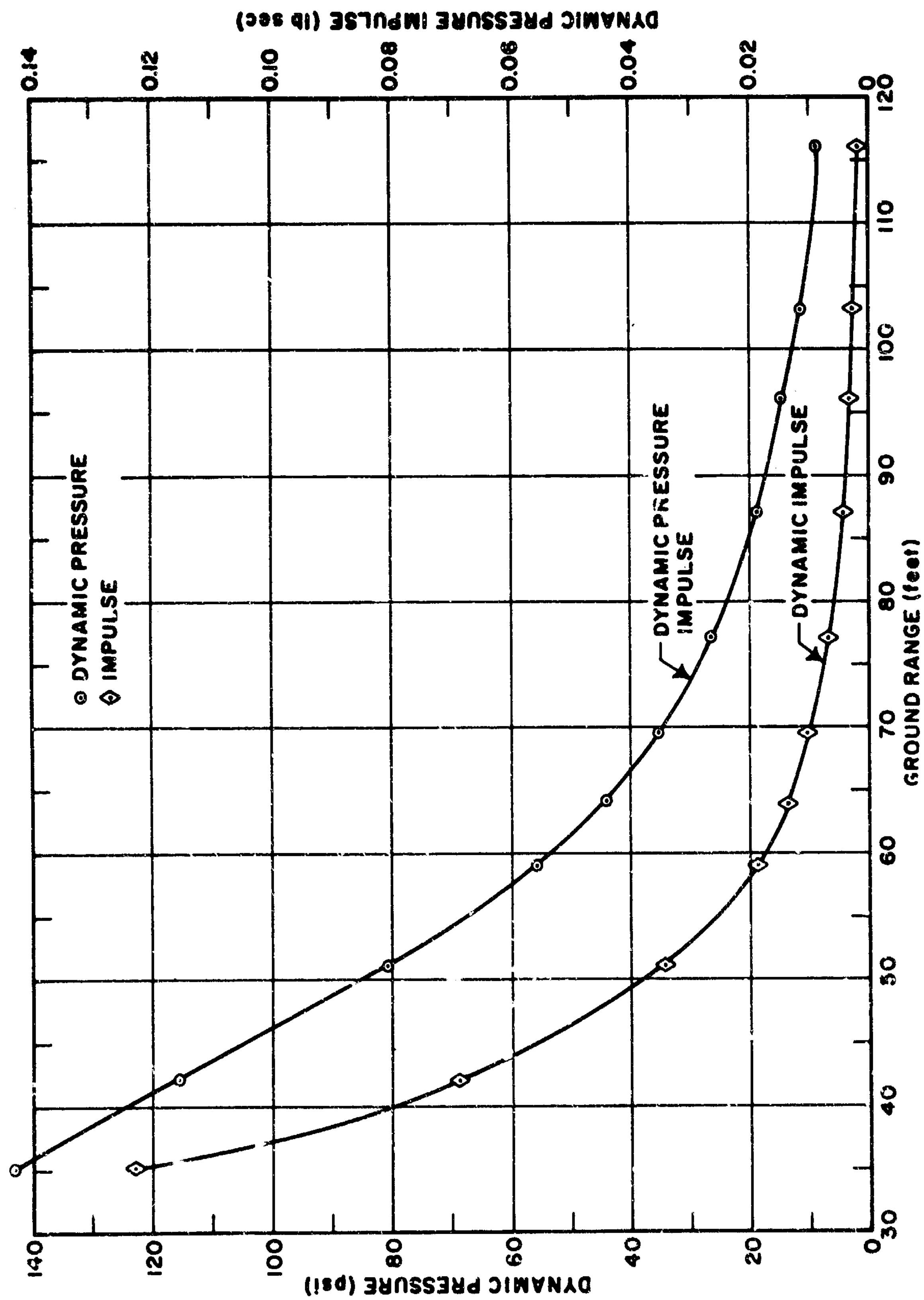

Figure 9. Dynamic Pressure and Dynamic Pressure Impulse vs. Ground Range.

SECTION V

CONCLUSIONS

The experimental data included in this report are believed by the experimenters to be some of the best data of this type available. If this is the case, one can conclude that the parameters measured in this type of experiment are more easily and accurately determined by SHELL than by experimental measurement. Further, parameters not measured in this experiment, such as dynamic pressure, dynamic pressure impulse, and velocity, are also more easily and precisely determined by SHELL. Even though the discrepancy in the second shock arrival time is of secondary significance, it should not be ignored. This discrepancy does not affect the principal parameters of the problem.

Included in Appendix I are photographs of the experiment and calculated contours both occurring at approximately the same times. The initial shock reflection, Mach stem formation, and second shock reflection are much more easily distinguished on the contours than on the films.

In view of the comparisons between the SHELL method and experimental measurement presented in this report, much time, effort, and expense could be saved with pre-experiment calculations. Instrument calibration and position could be determined to achieve maximum utilization. By using the results of a calculation such as this, much better field data could be collected, and from these field data the codes could be improved to make even more accurate calculations.

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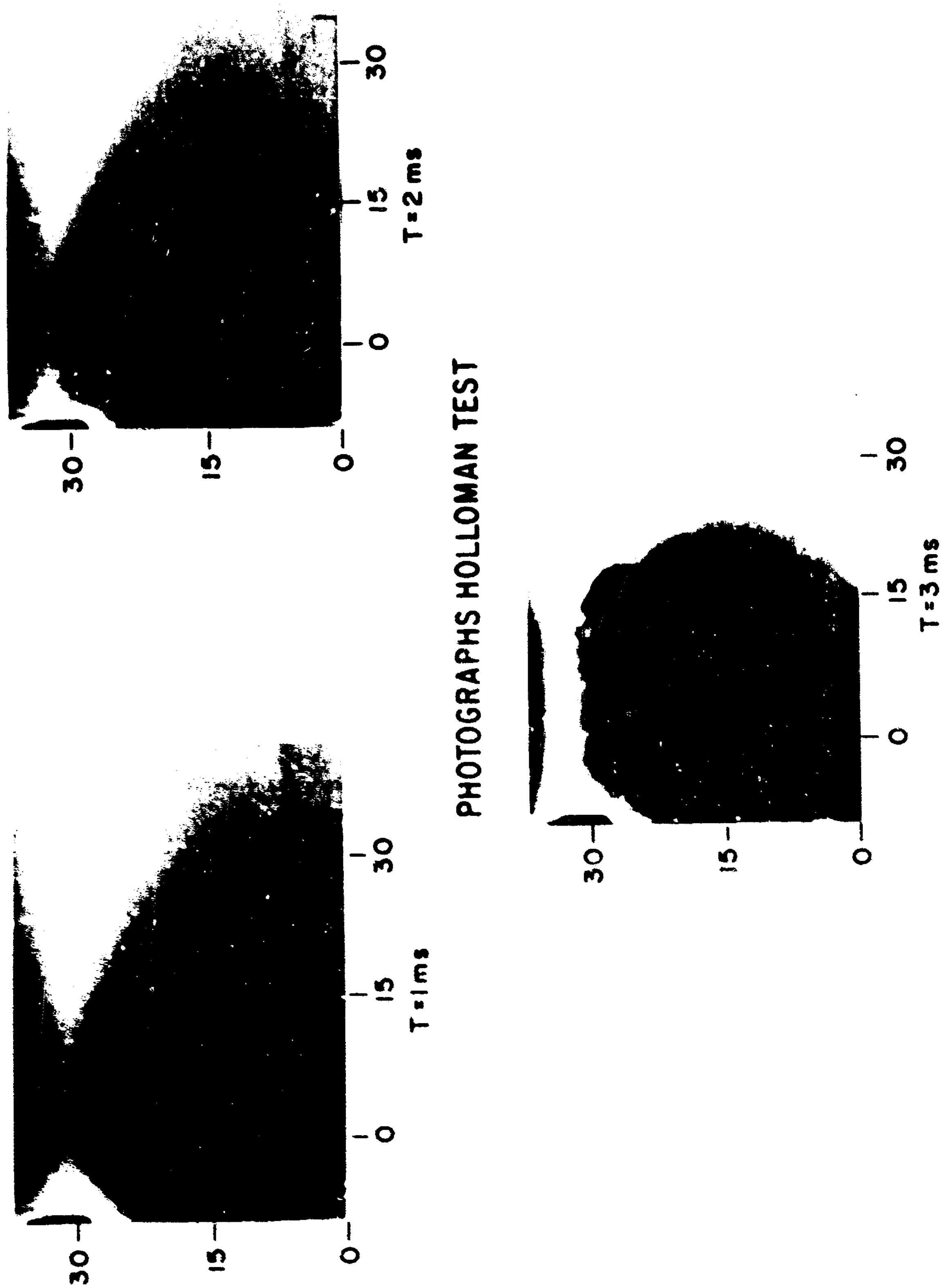
Appendix I

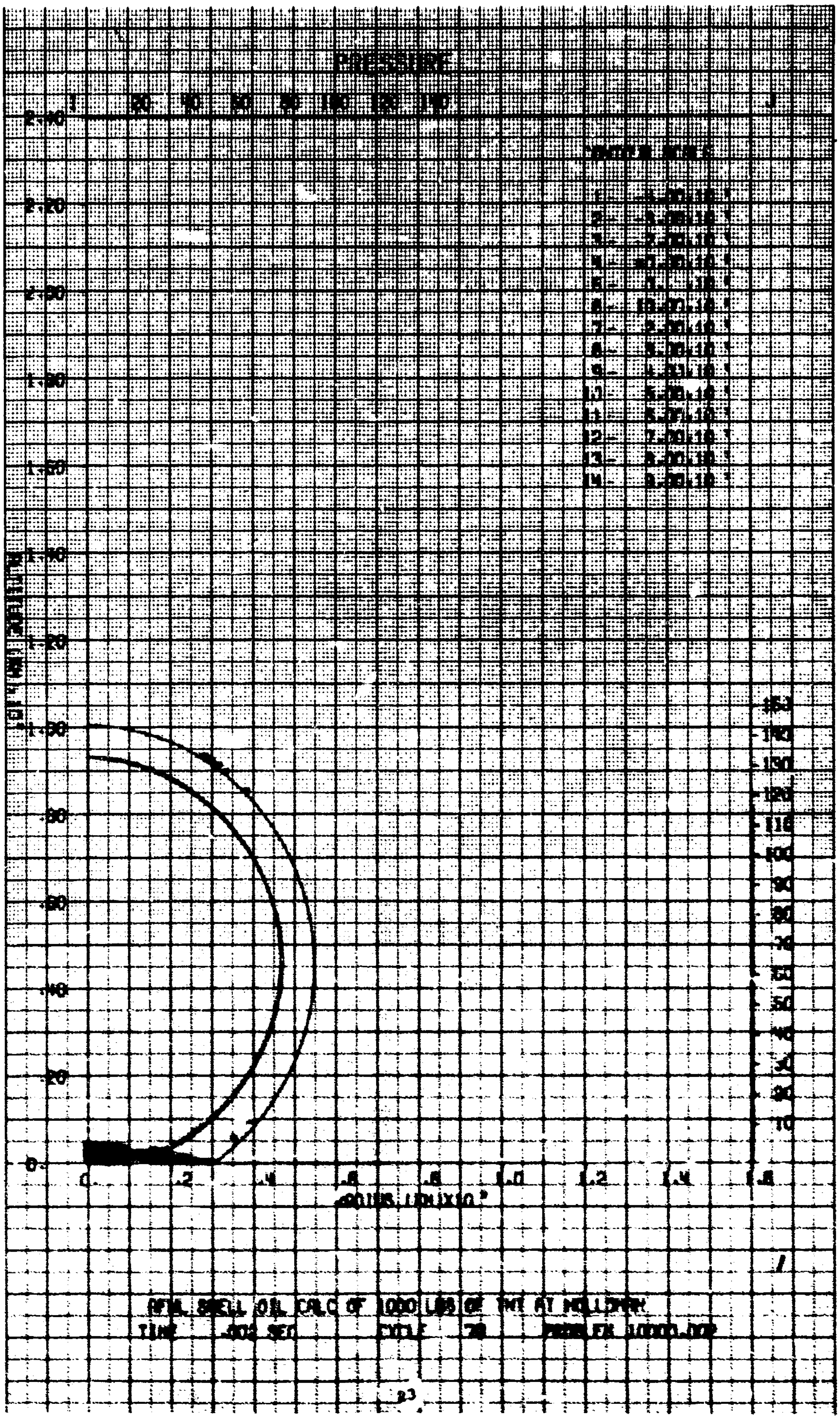
CONTOURS, VECTORS, AND PHOTOS

The first three figures contained in this appendix are photographs of the detonation at 1, 2, and 3 milliseconds. The edge of the fireball in the photographs corresponds to the edge of the TNT detonation products. These in turn correspond to the particles on the interface seen in the computer plots, but the air shock is not visible in these photographs. Comparisons between photographs and plots are possible but difficult due to the quality of the film. A more useful comparison can be found in Appendix II.

The plots included in Appendix I indicate the formation and growth of the Mach stem with the associated velocity, pressure, and density distributions.



PHOTOGRAPHS HOLLOMAN TEST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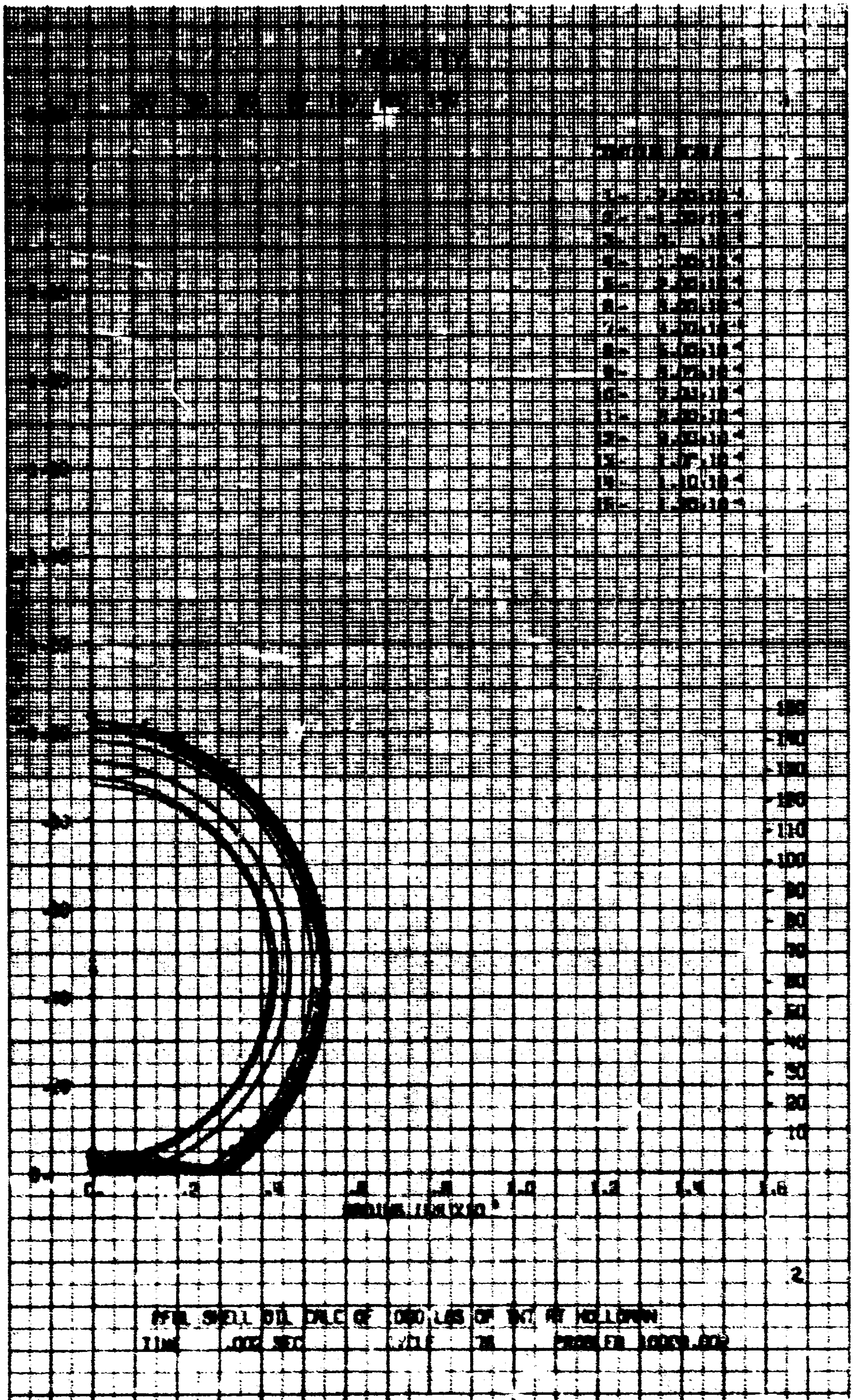

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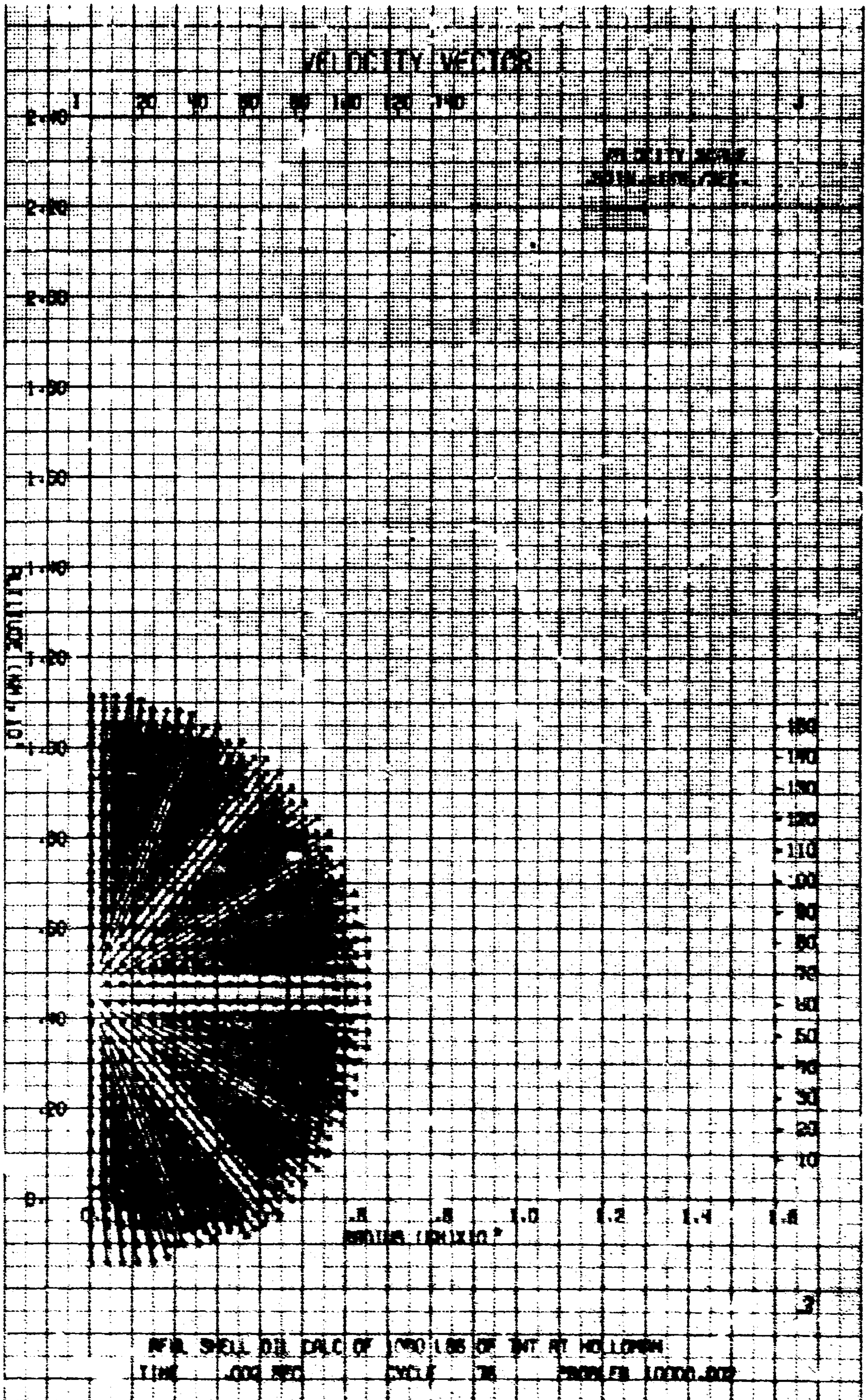
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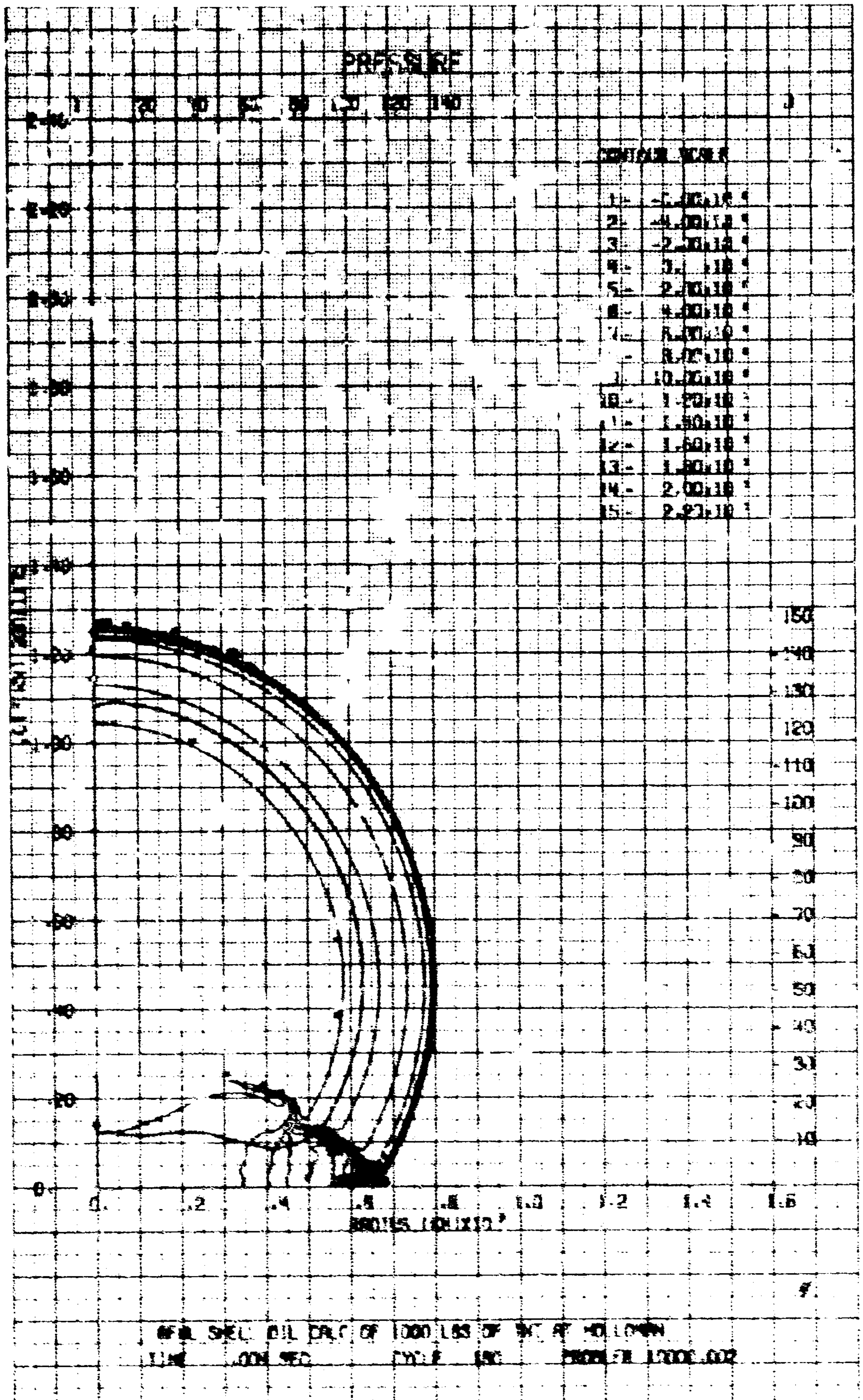
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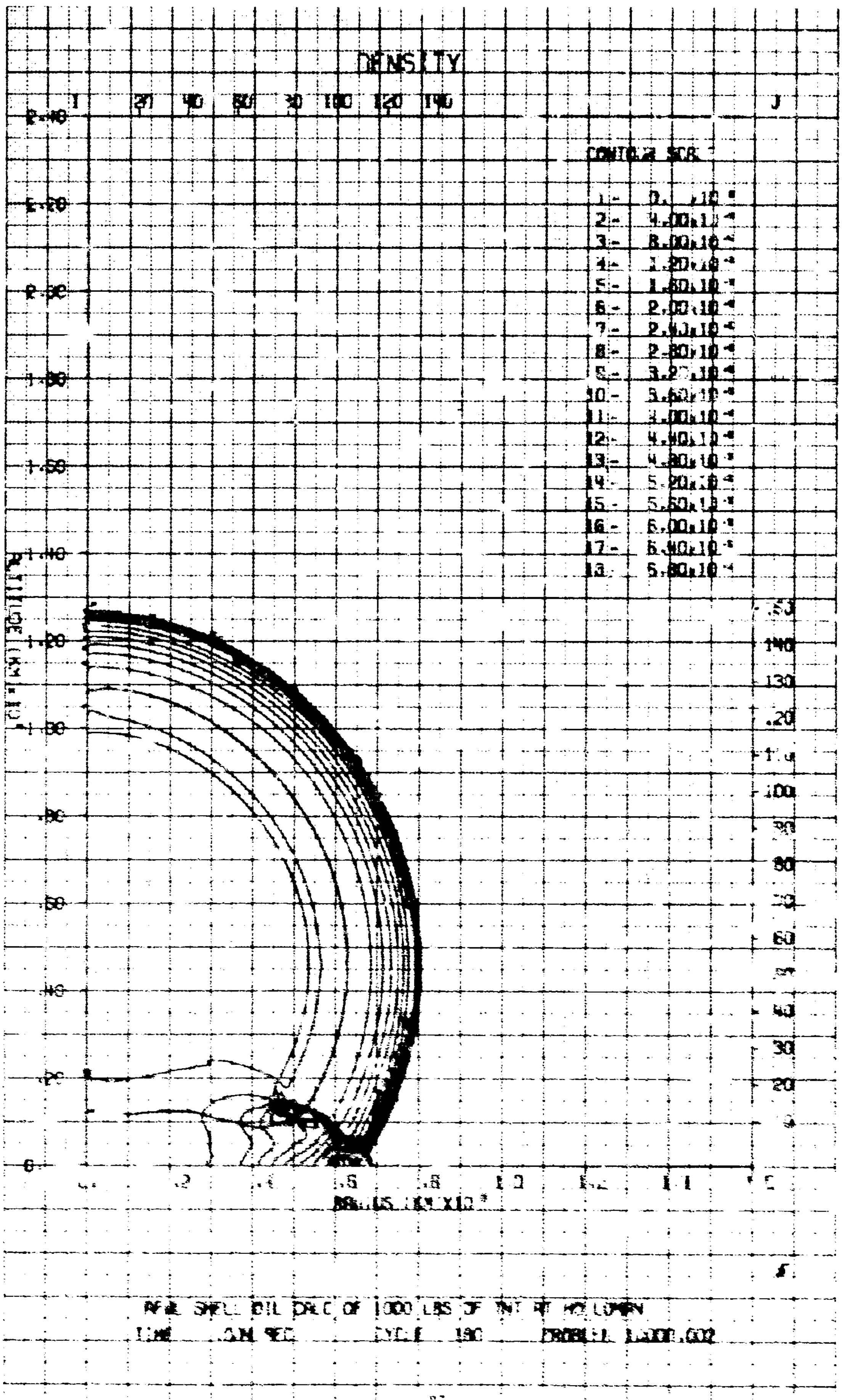
DENSITY
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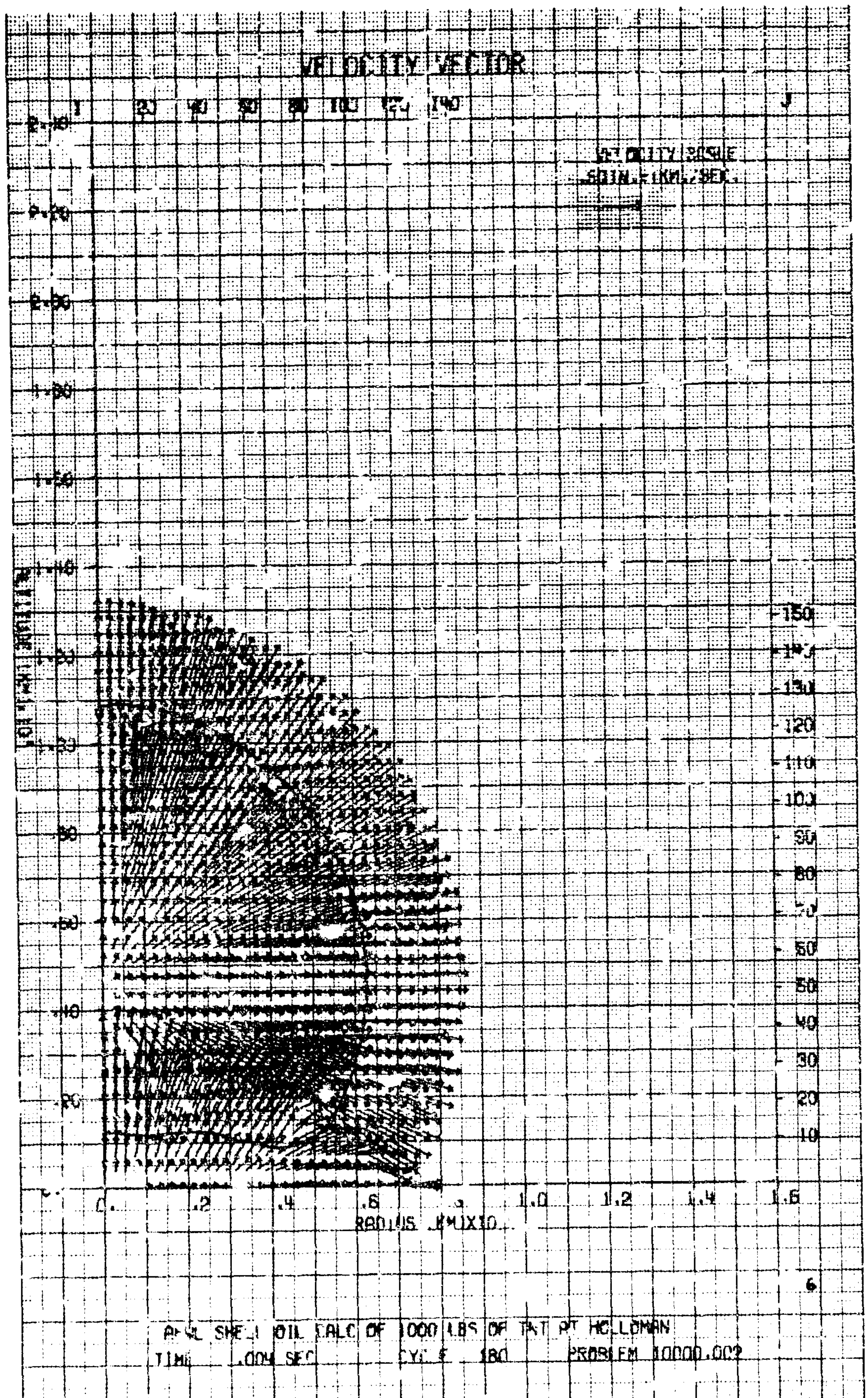
AFWL SHELL DIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
CYCLE 190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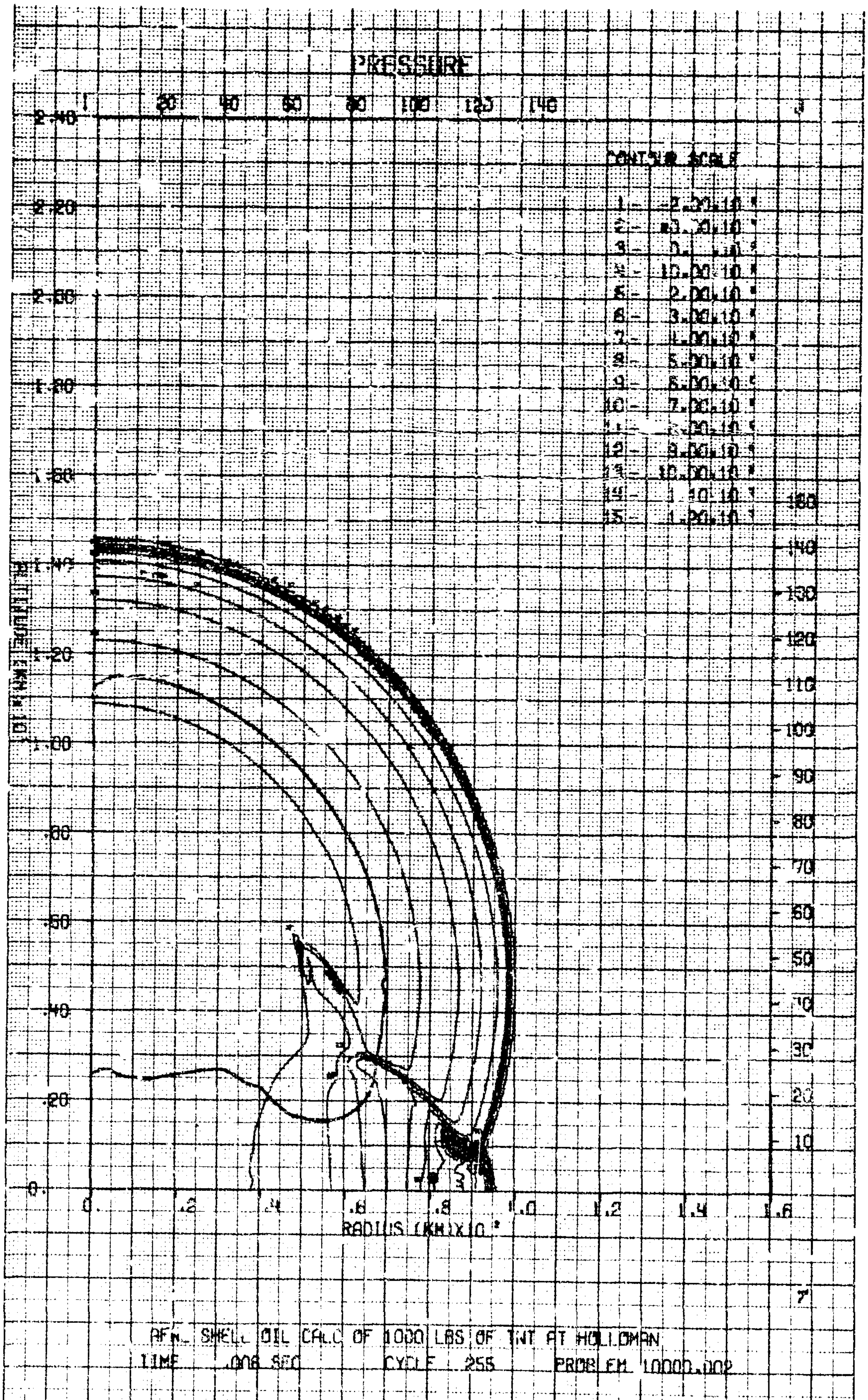
TIME .004 SEC CYC # 180 PROBLEM 10000.002



PRESSURE
CONTOUR SCALE
RADIUS (KM)X10
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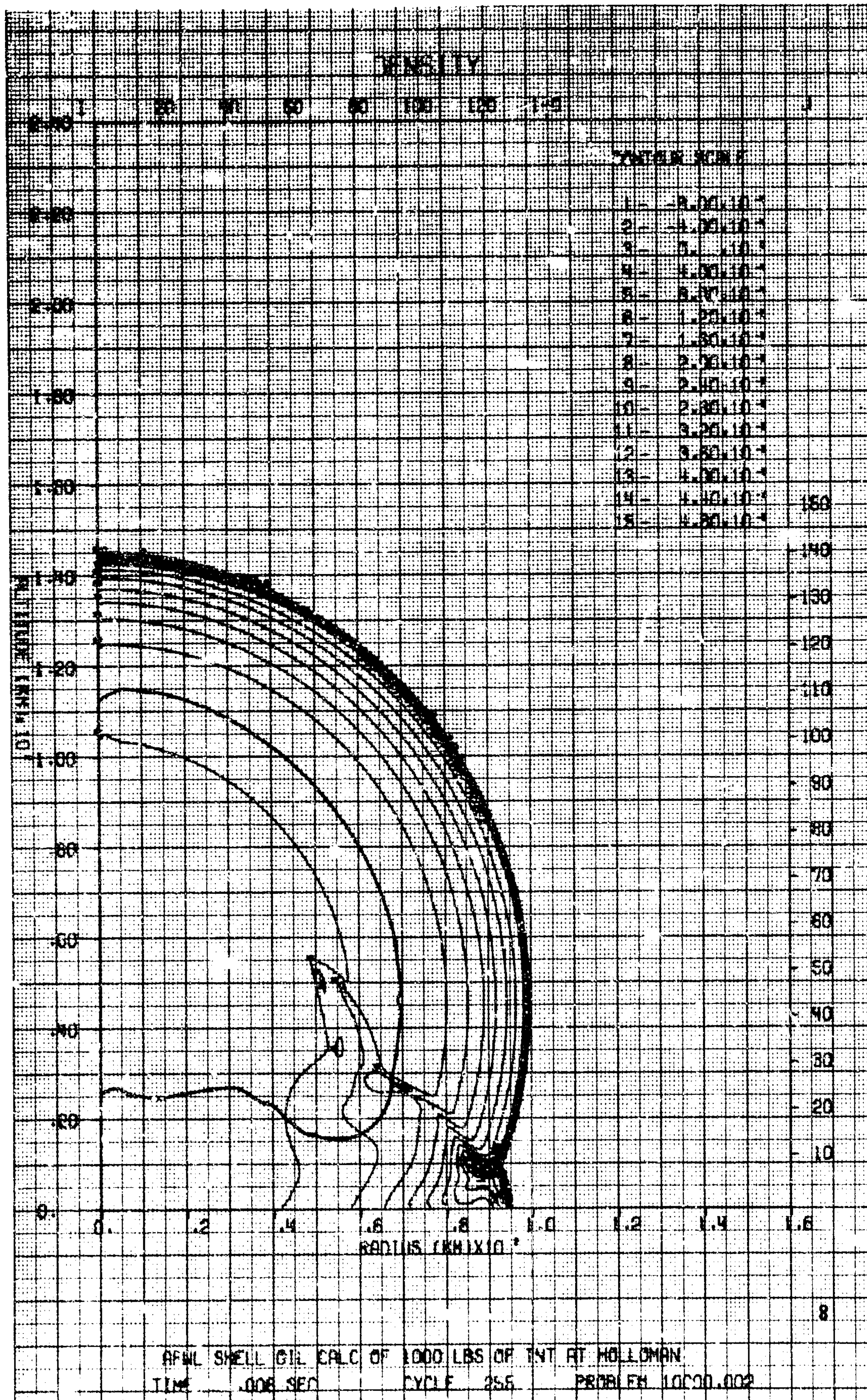
AFW... SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .008 SEC CYCLE 255 PROBLEM 10000.002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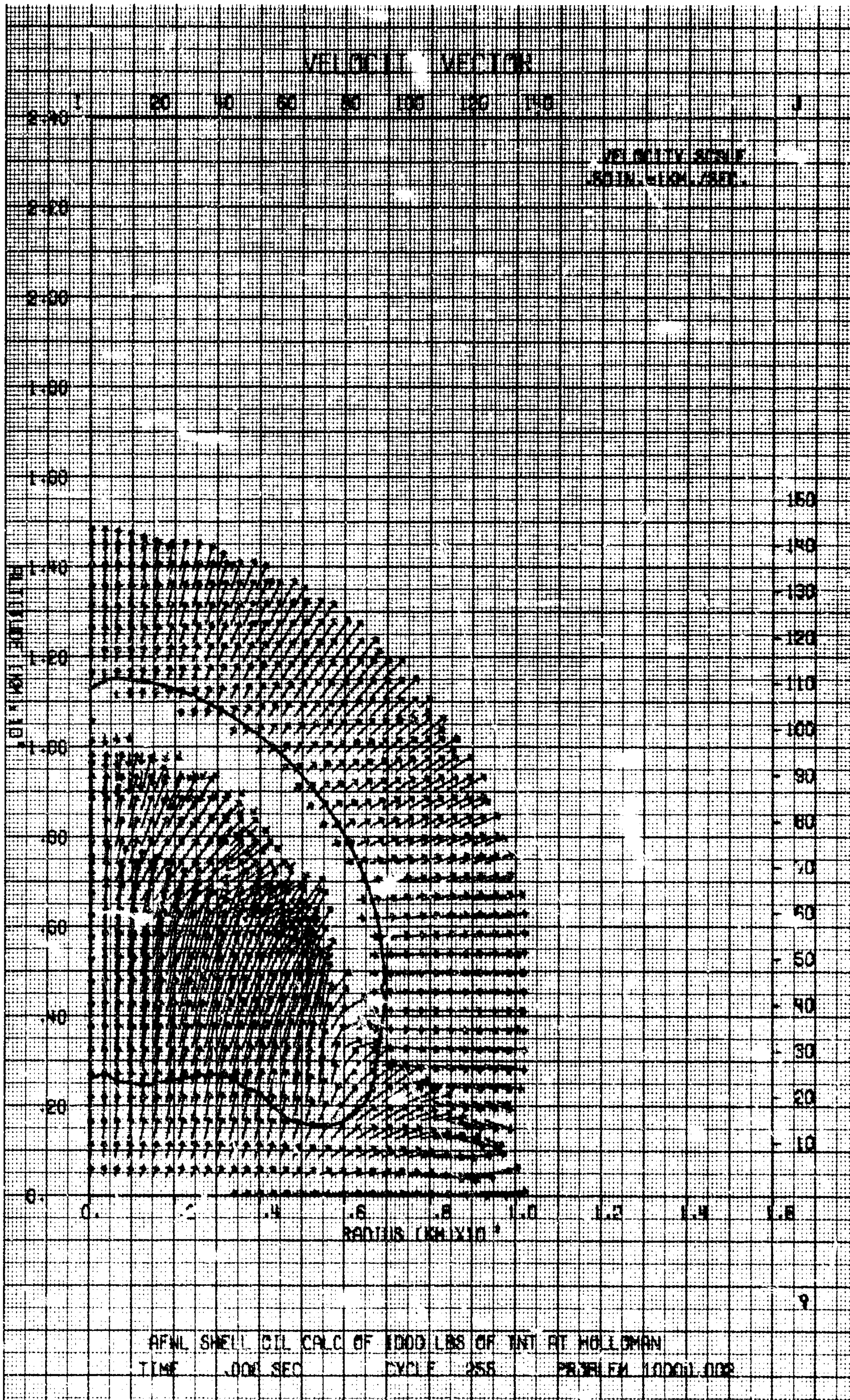
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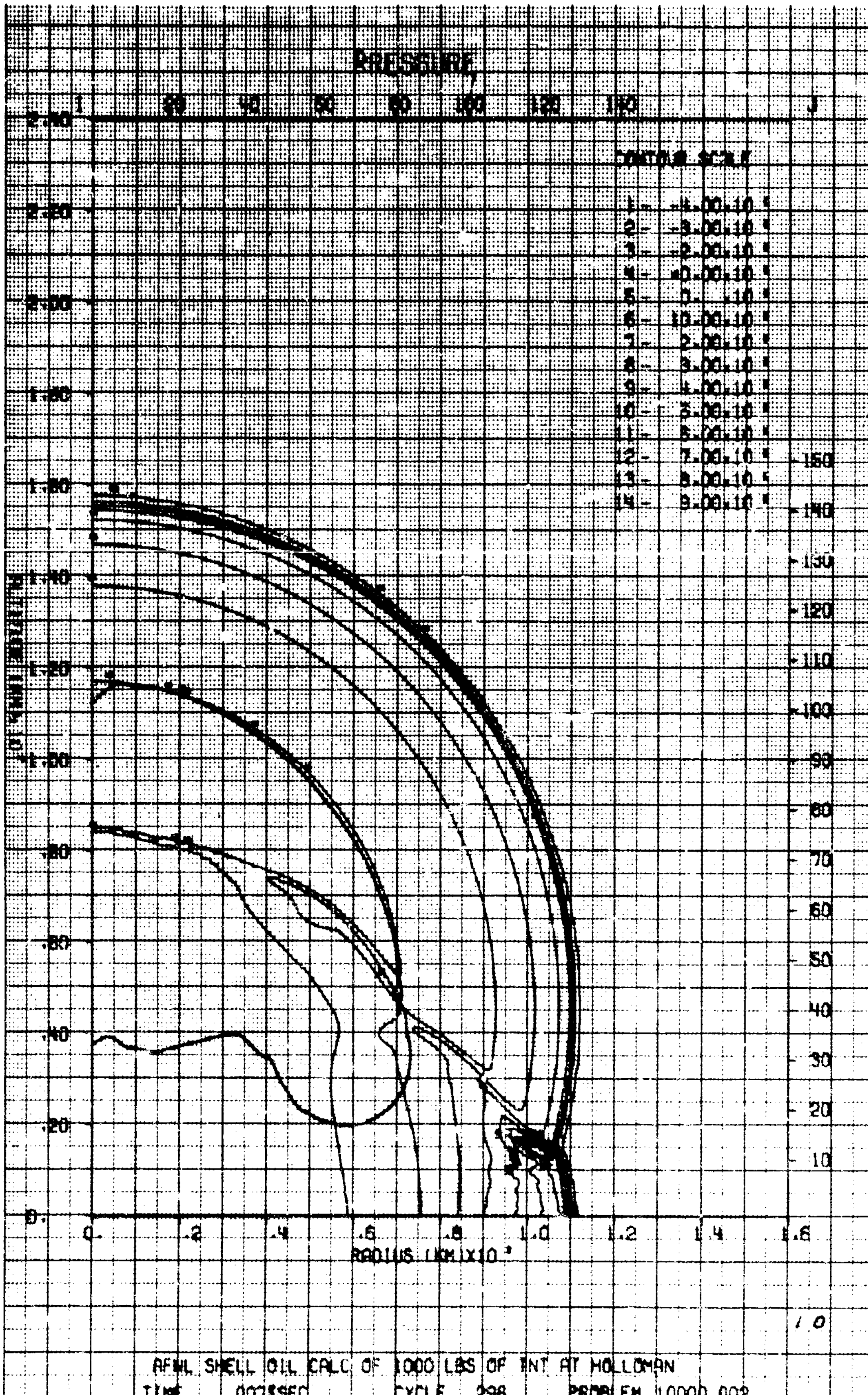
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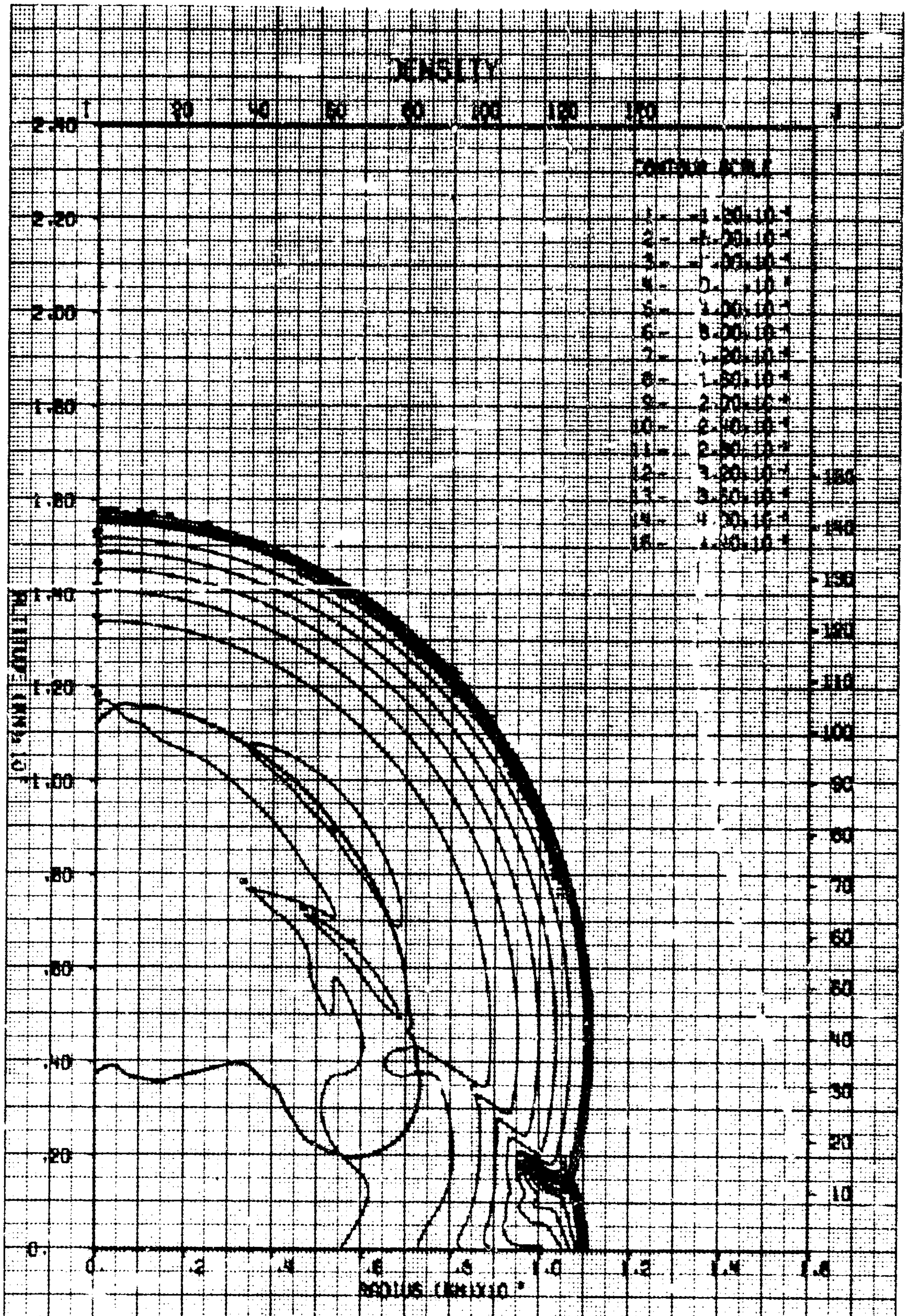

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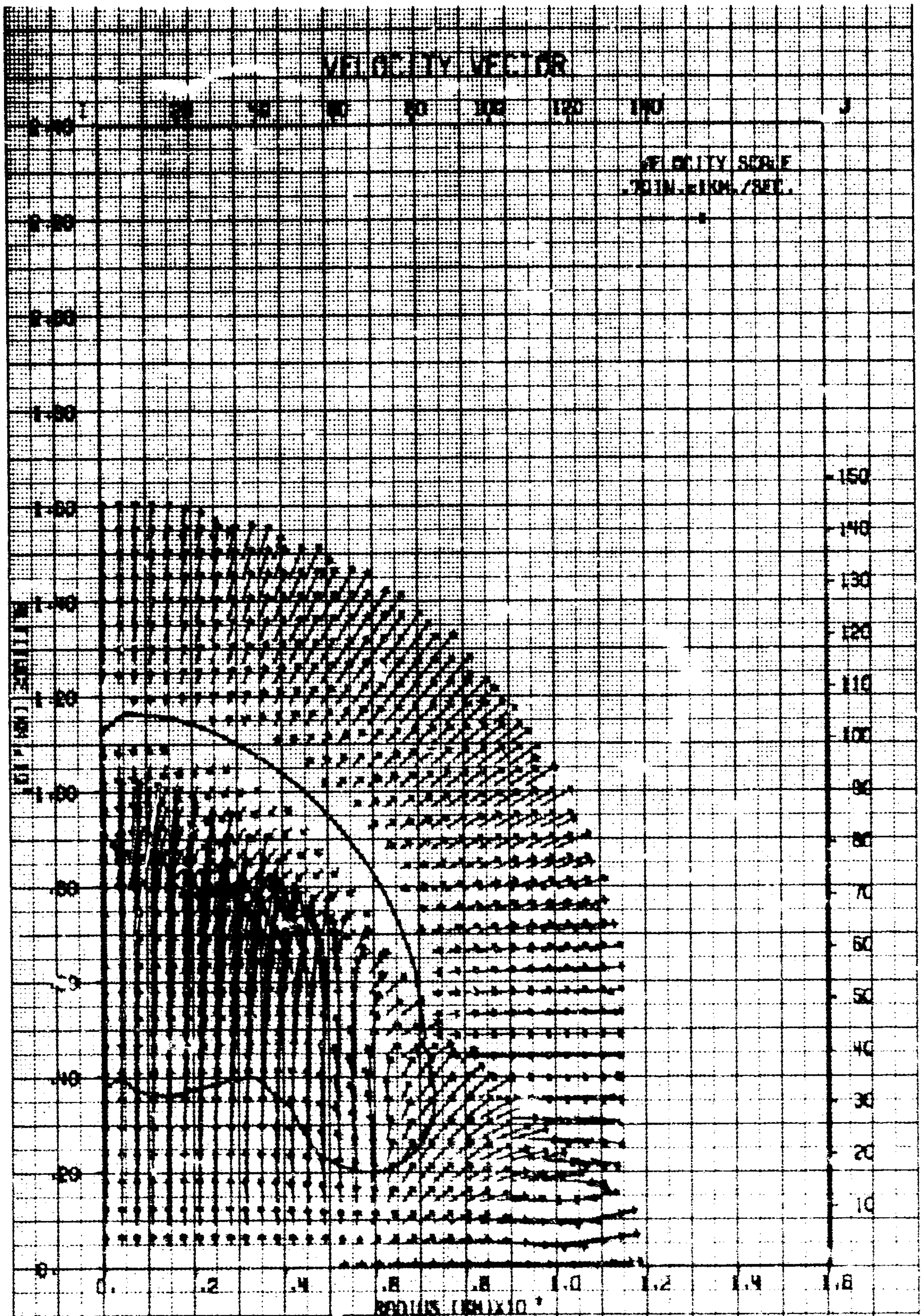

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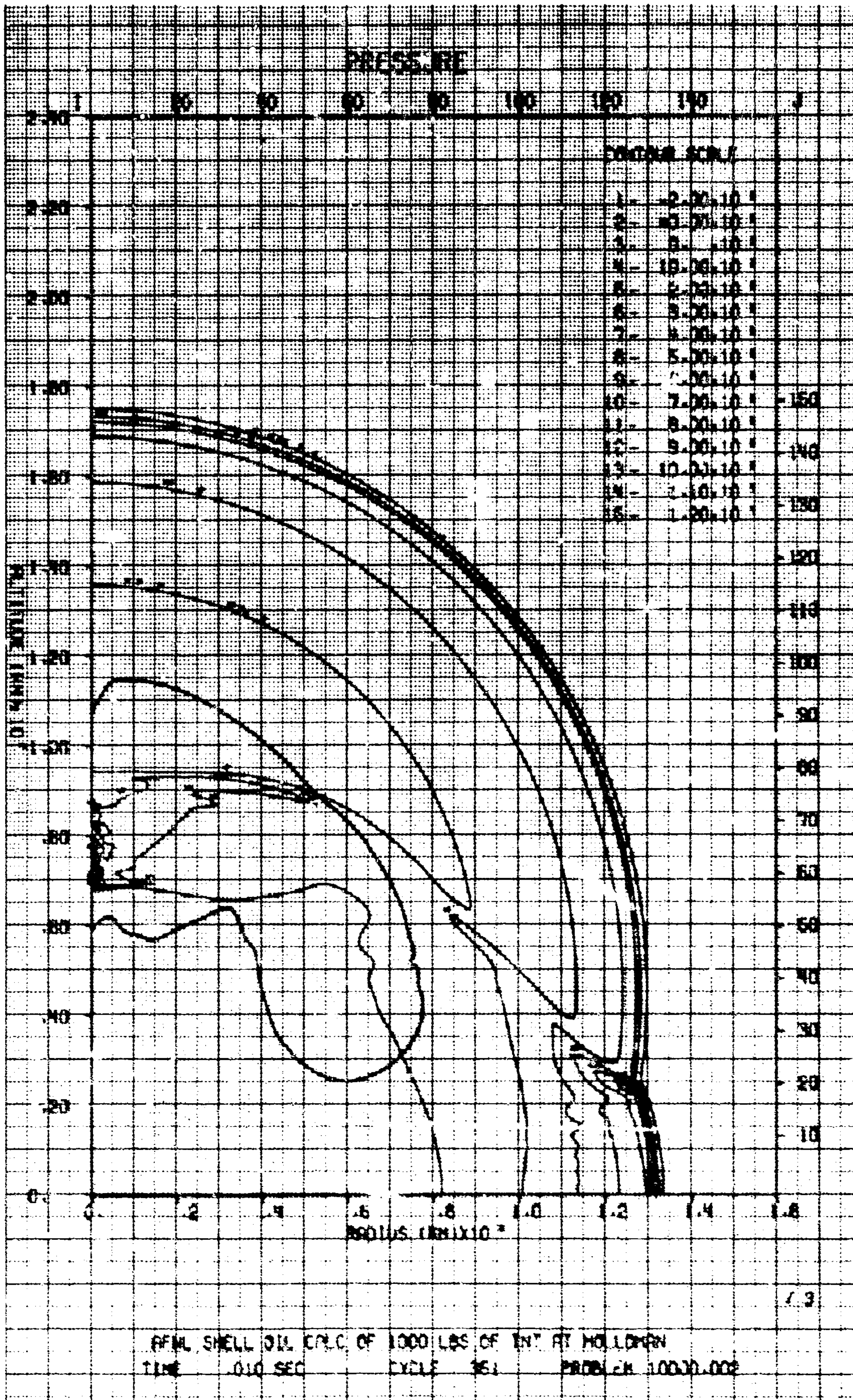
PRESSURE
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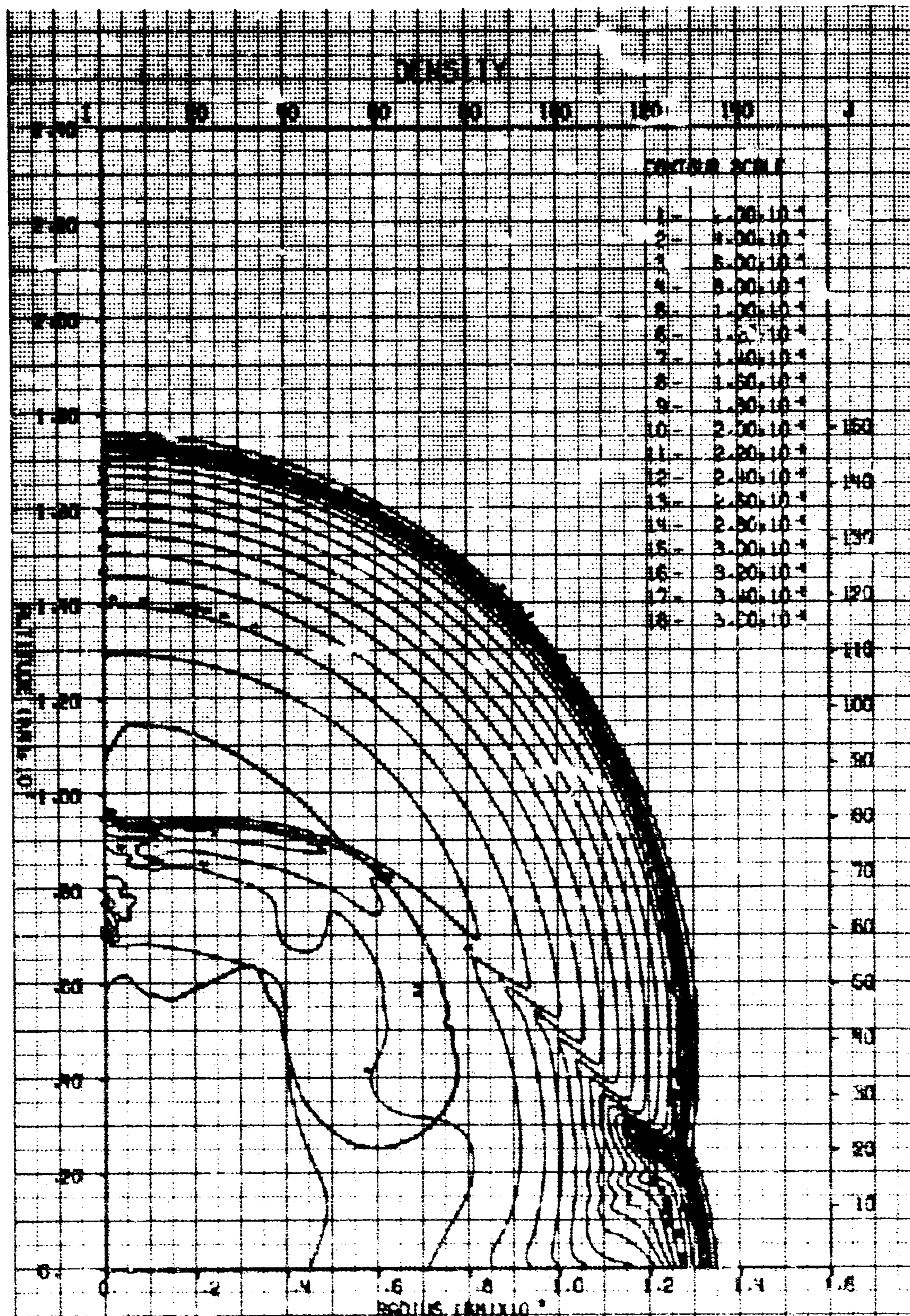

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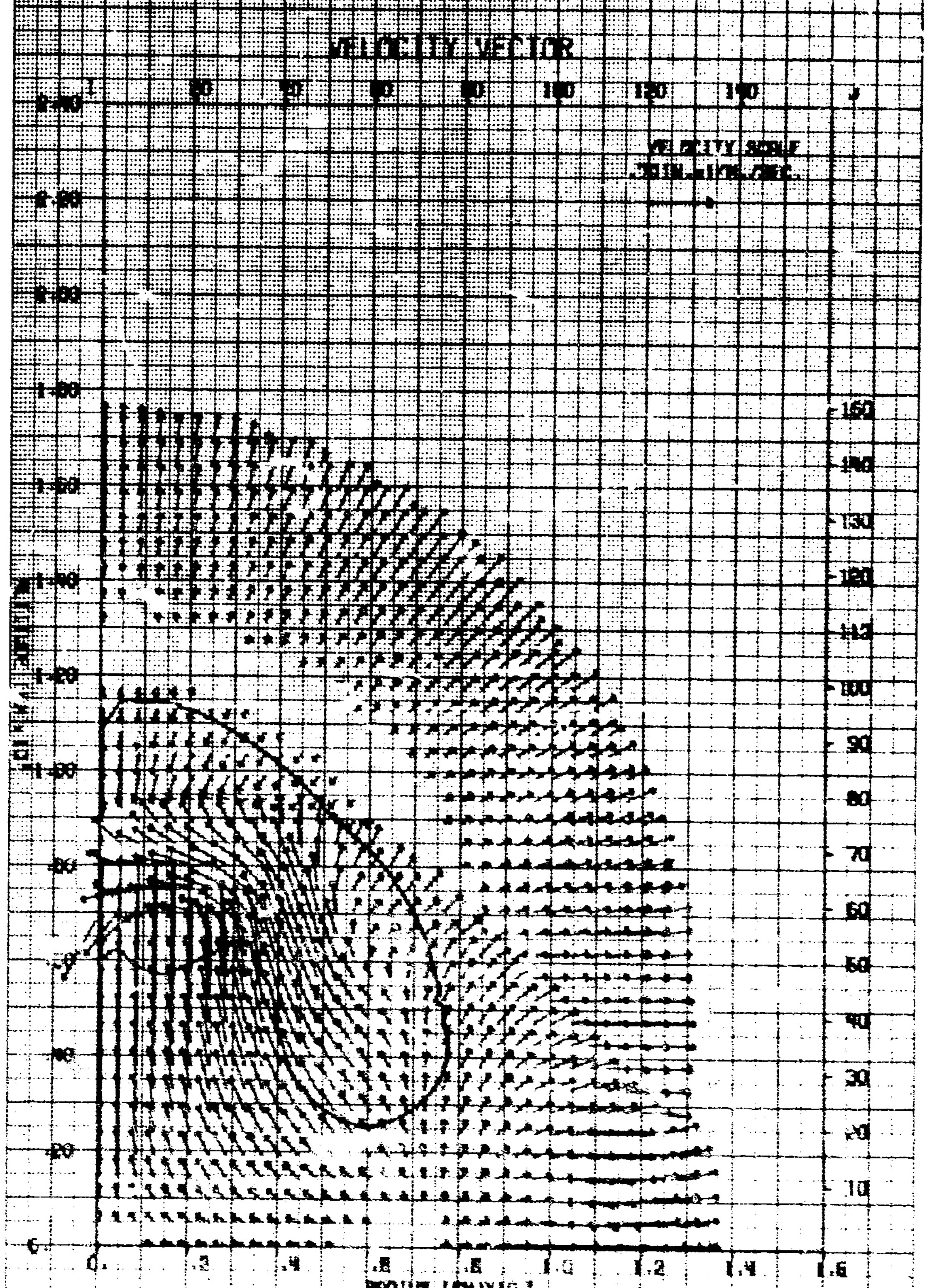

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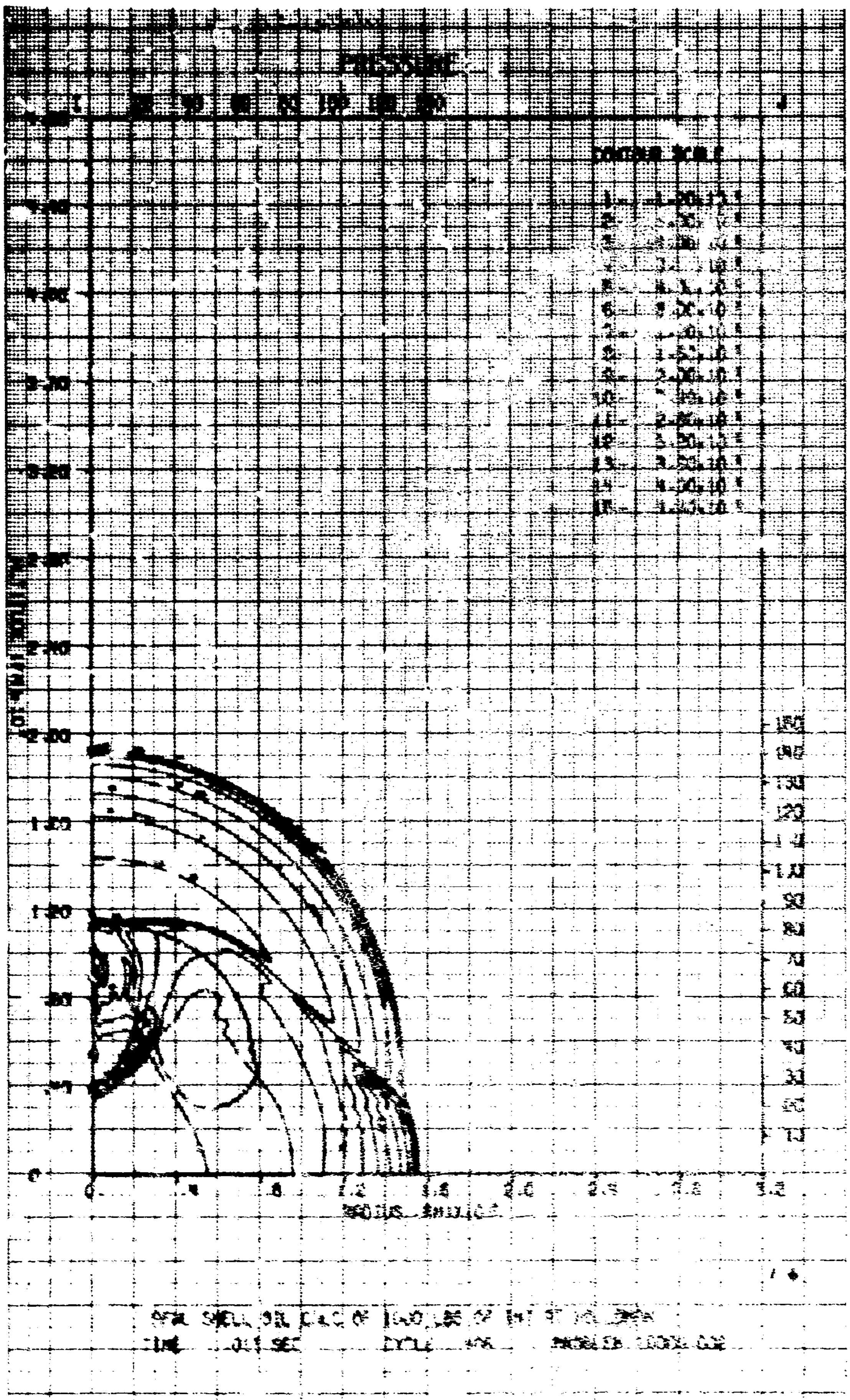
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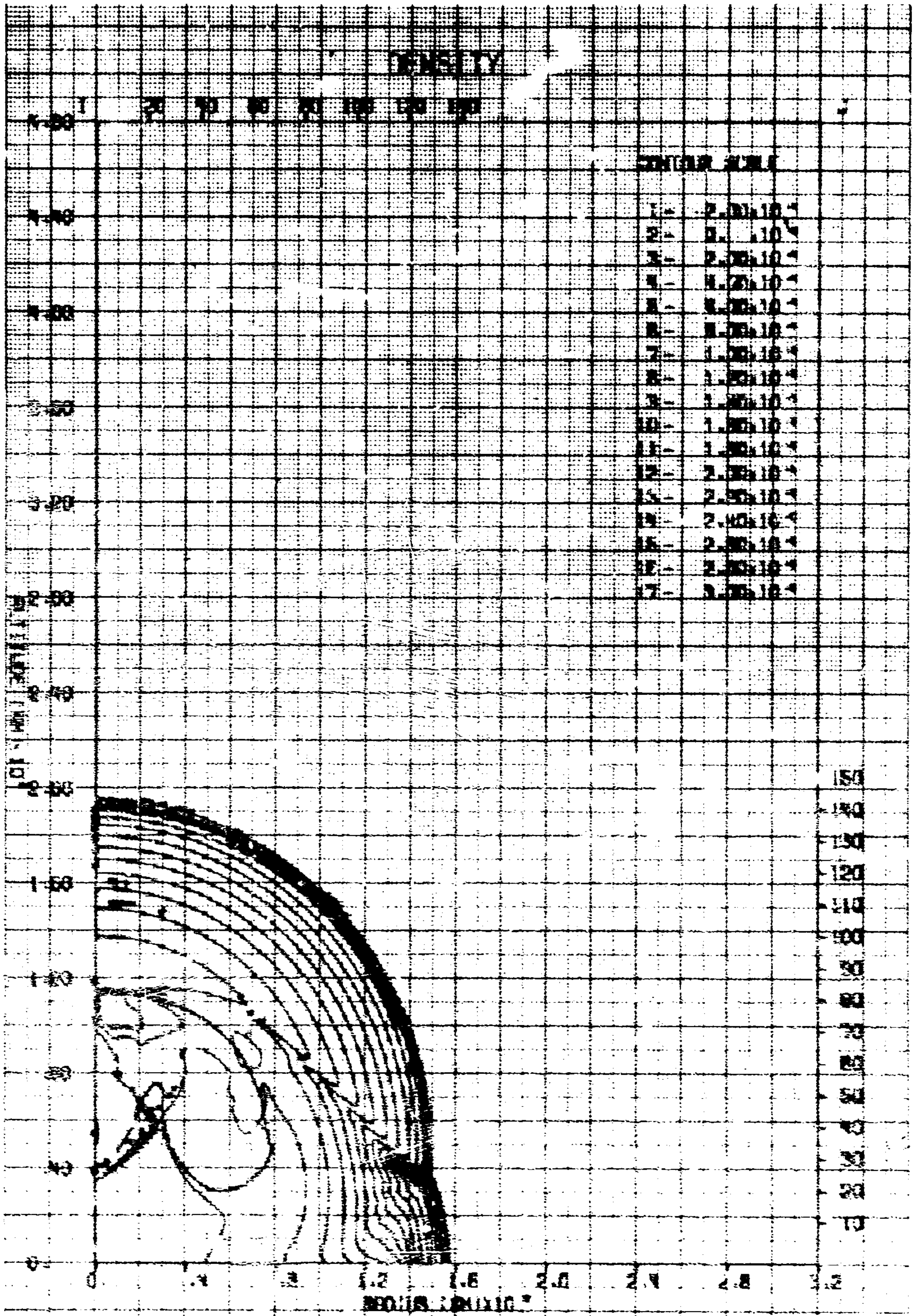
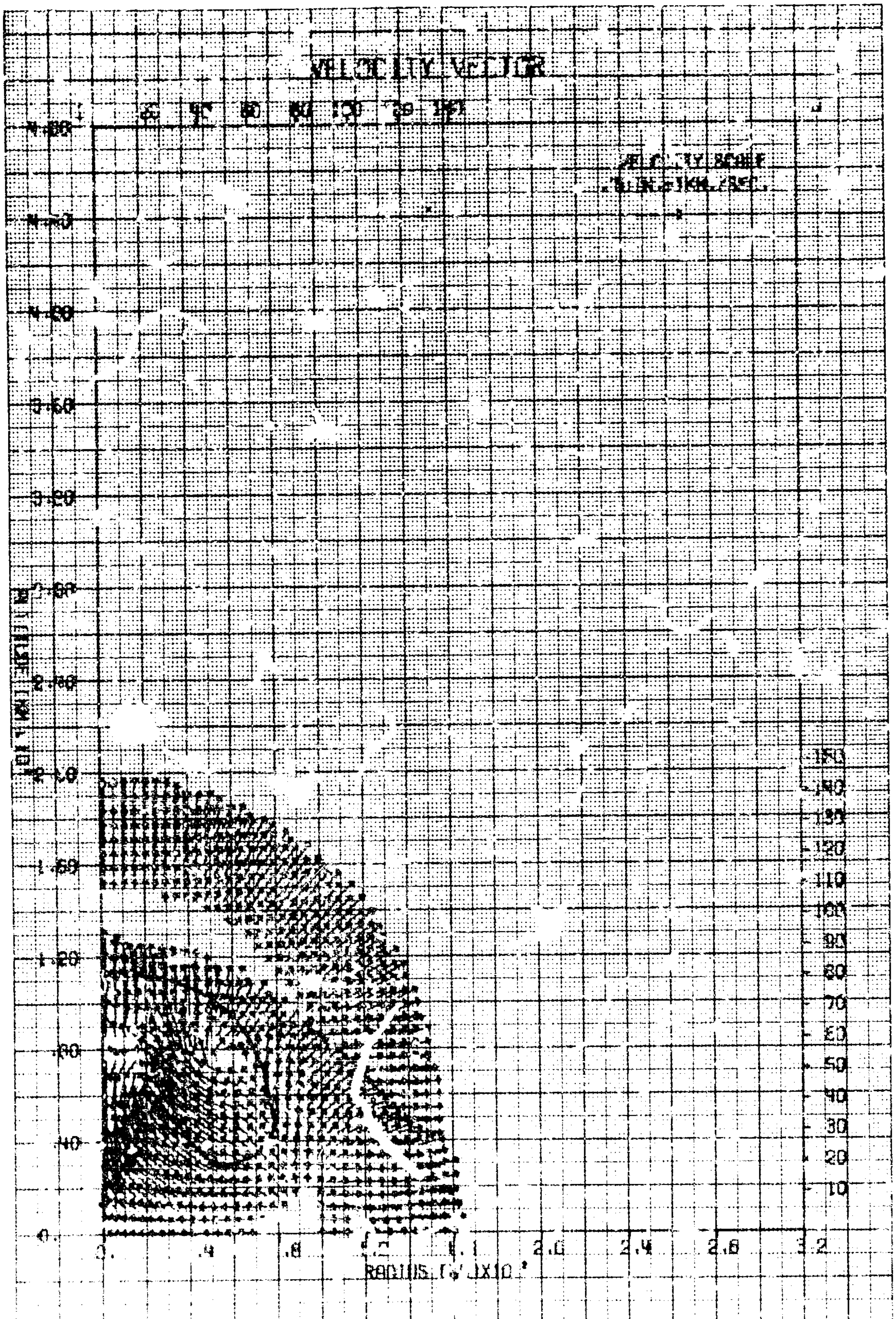
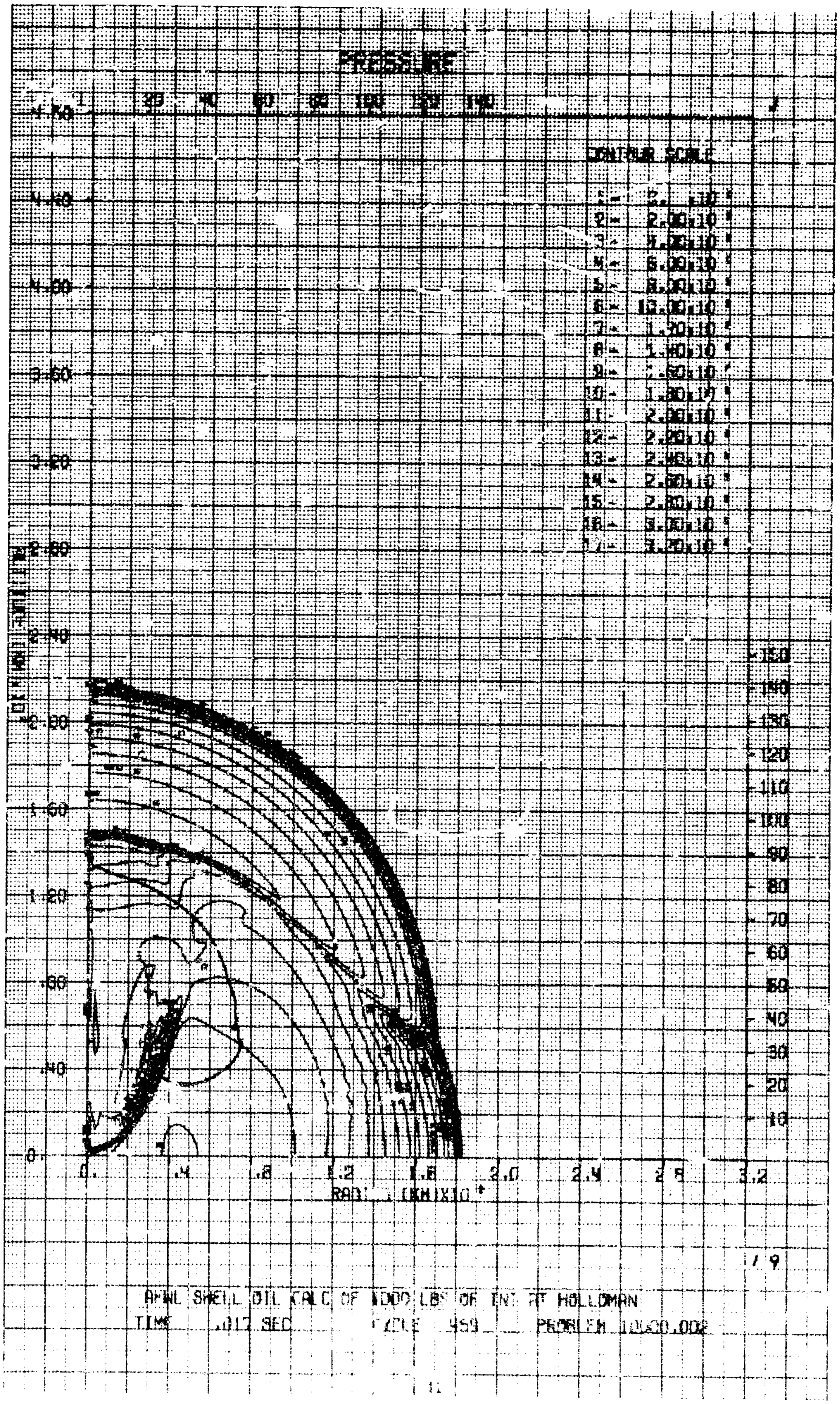
CONTOUR SCALE

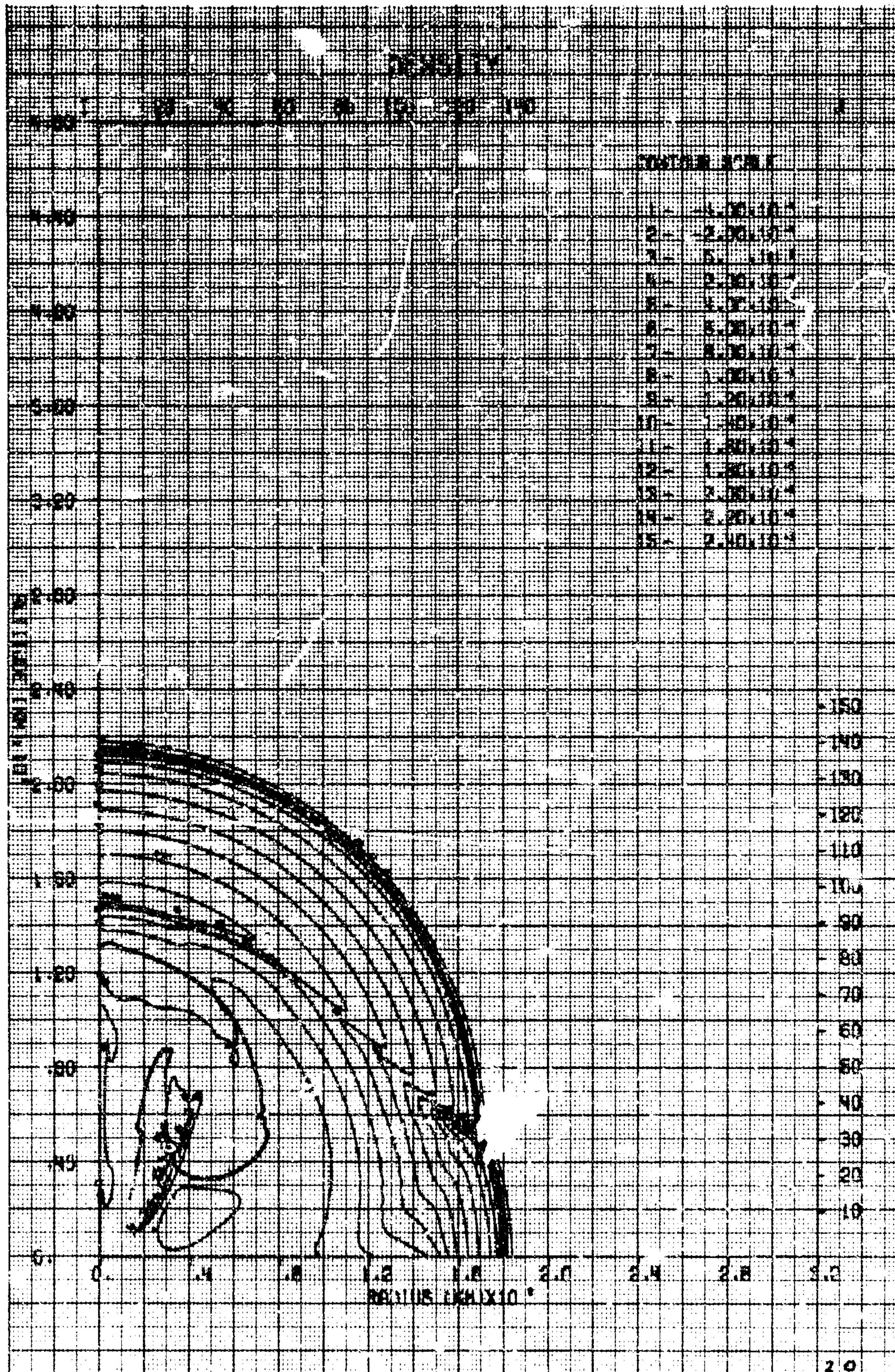


[illegible] SHELL [illegible] OF 1000 LBS OF TNT AT [illegible]
TIME [illegible] SEC CYCLE 406 PROBLEM 10000.002

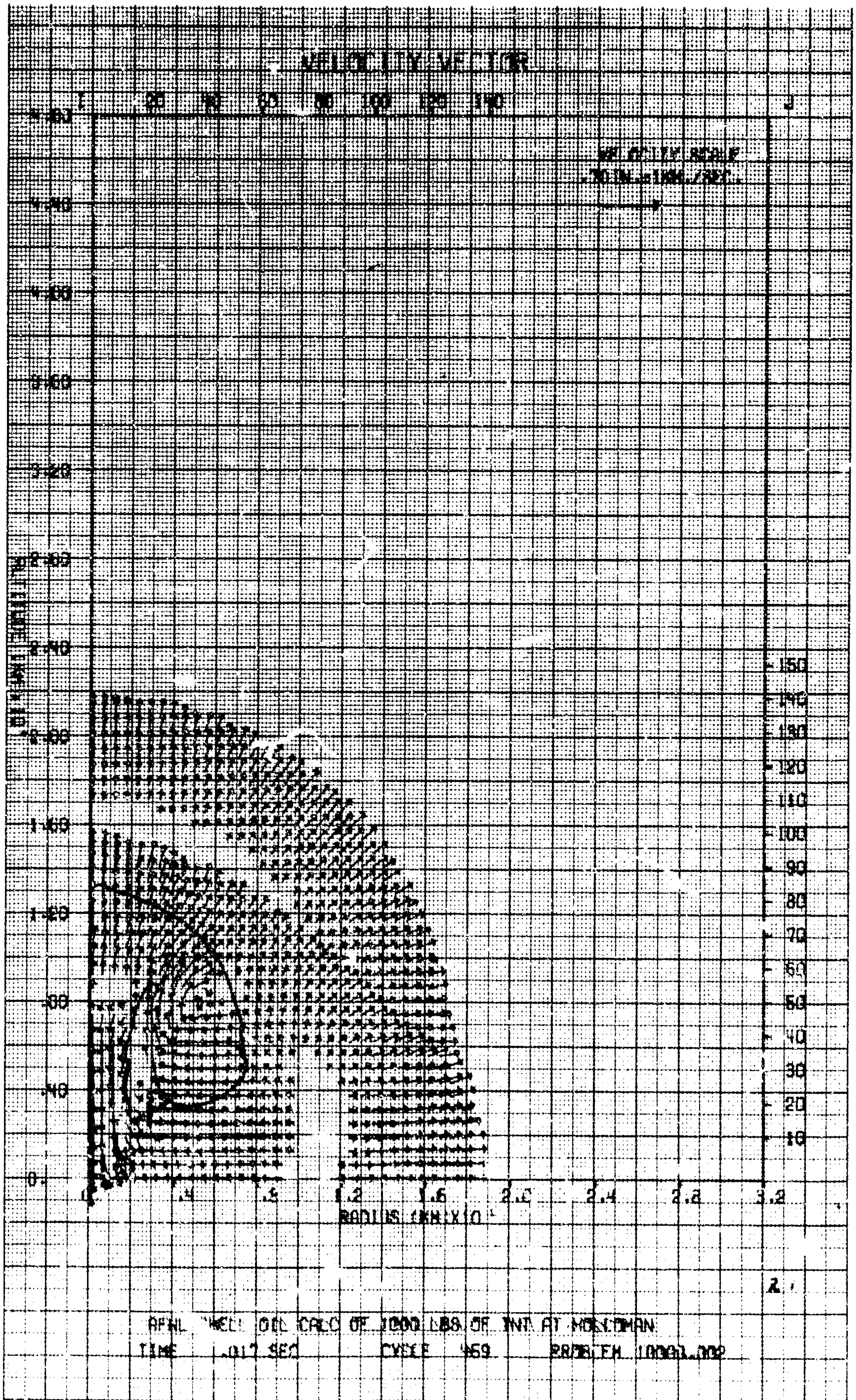


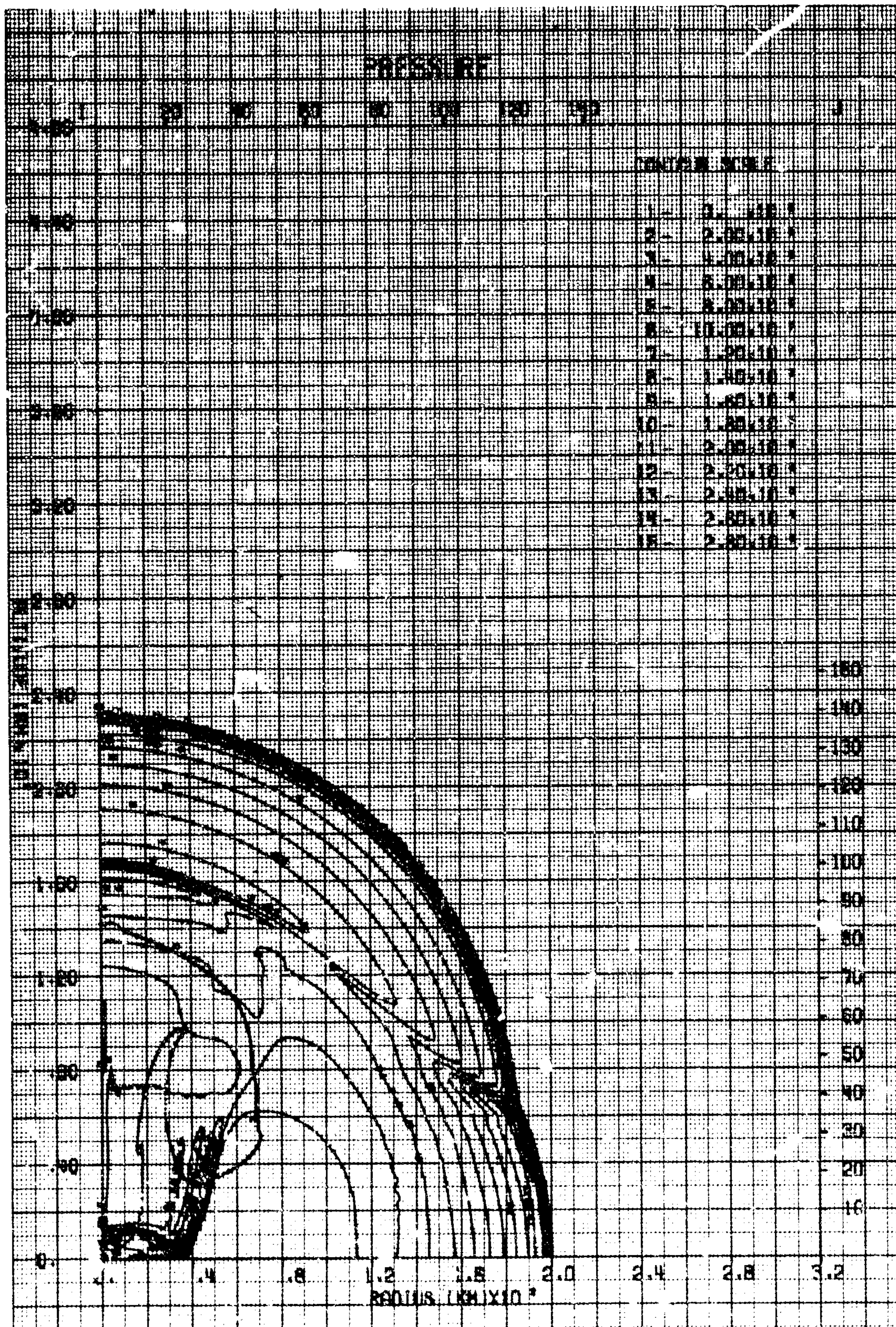
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .013 SEC CYCLE 406 PROBLEM 10000.002


PRESSURE
CONTOUR SCALE
2.00x10
4.00x10
6.00x10
8.00x10
1.20x10
1.40x10
1.80x10
2.00x10
2.20x10
2.40x10
2.60x10
2.80x10
3.20x10
0
.40
.80
1.20
1.60
2.00
2.40
2.80
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .017 SEC
PROBLEM

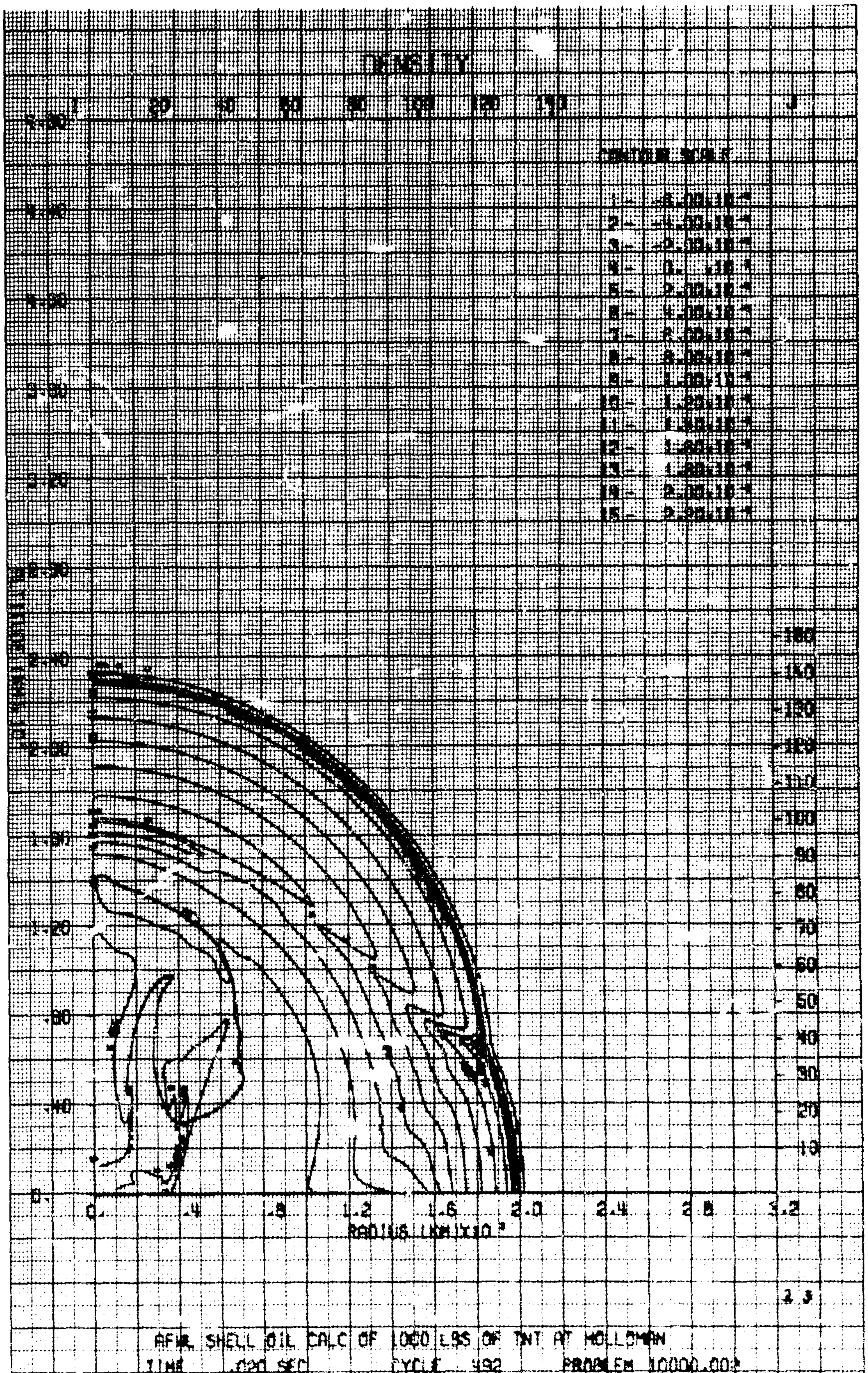


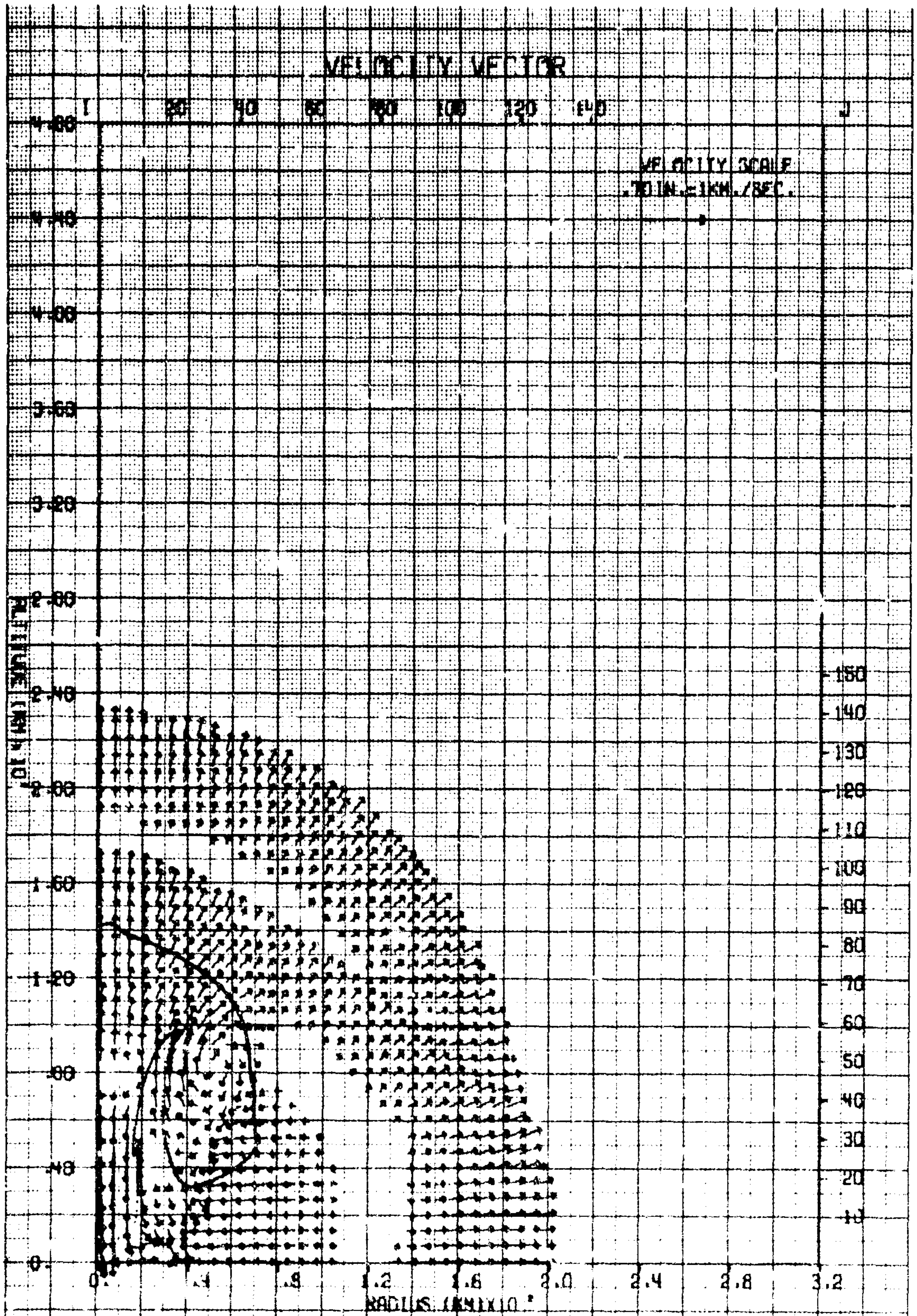
AFWL SHELL OIL CALC OF ?,000 LBS OF TNT AT HOLLOMAN
TIME .012 SEC CYCLE 459 PROBLEM 10000.002


VELOCITY VECTOR
VELOCITY SCALE
RADIUS (KM)
AFWL



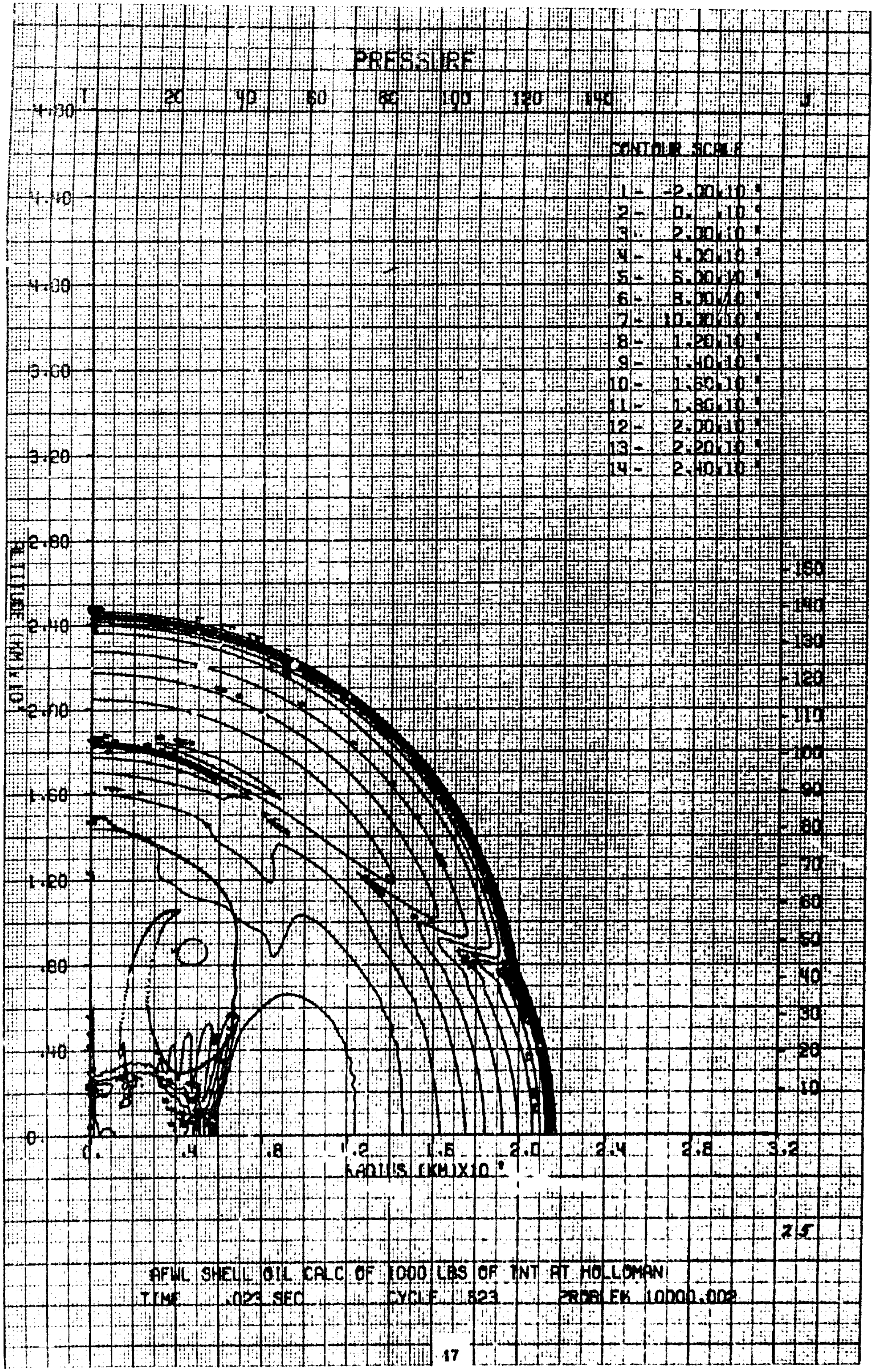
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .020 SEC CYCLE 492 PROBLEM 10000.002

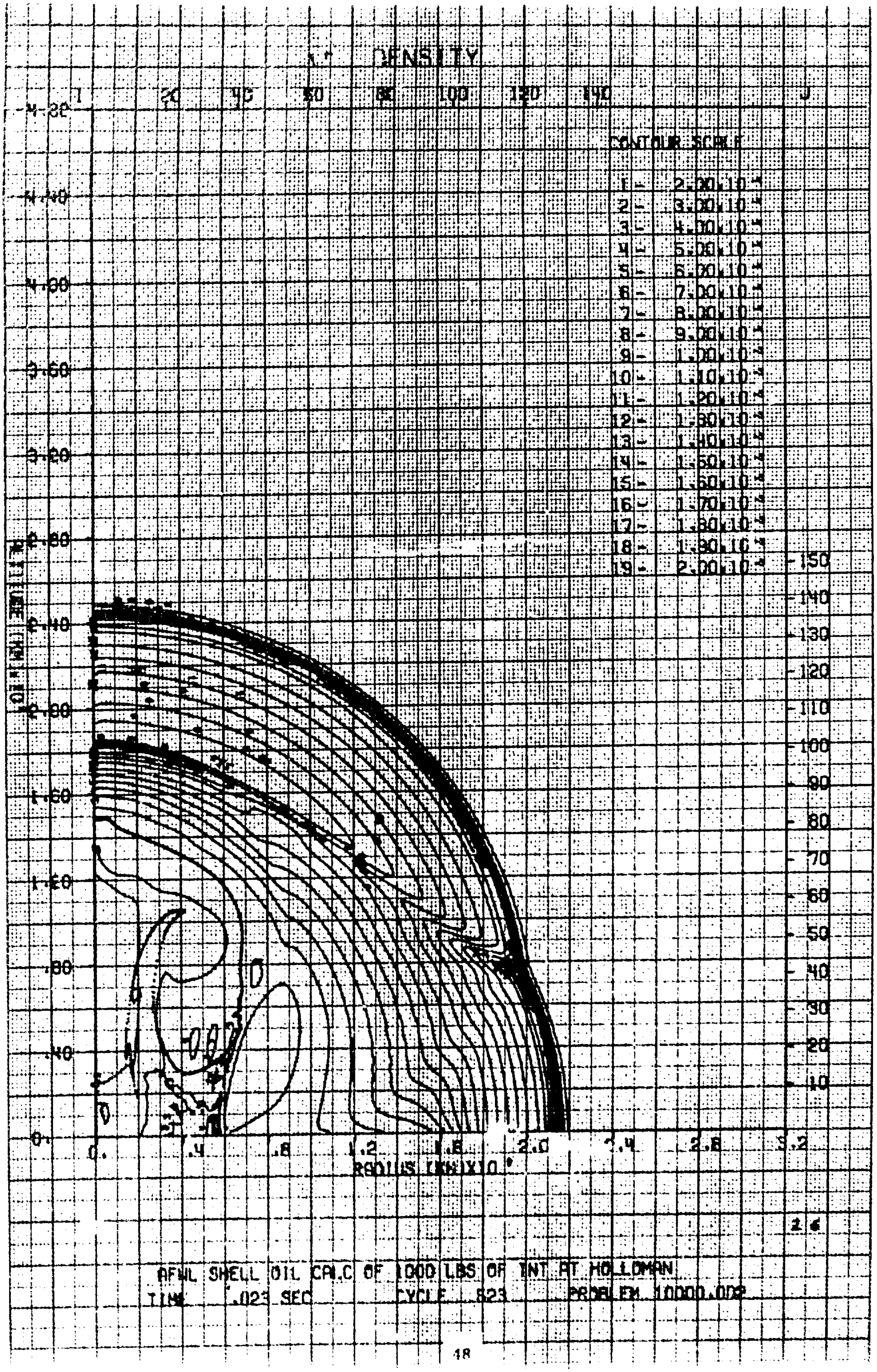

DENSITY
CONTOUR SCALE
RADIUS (KM)X10
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .020 SEC CYCLE 492 PROBLEM 10000.002

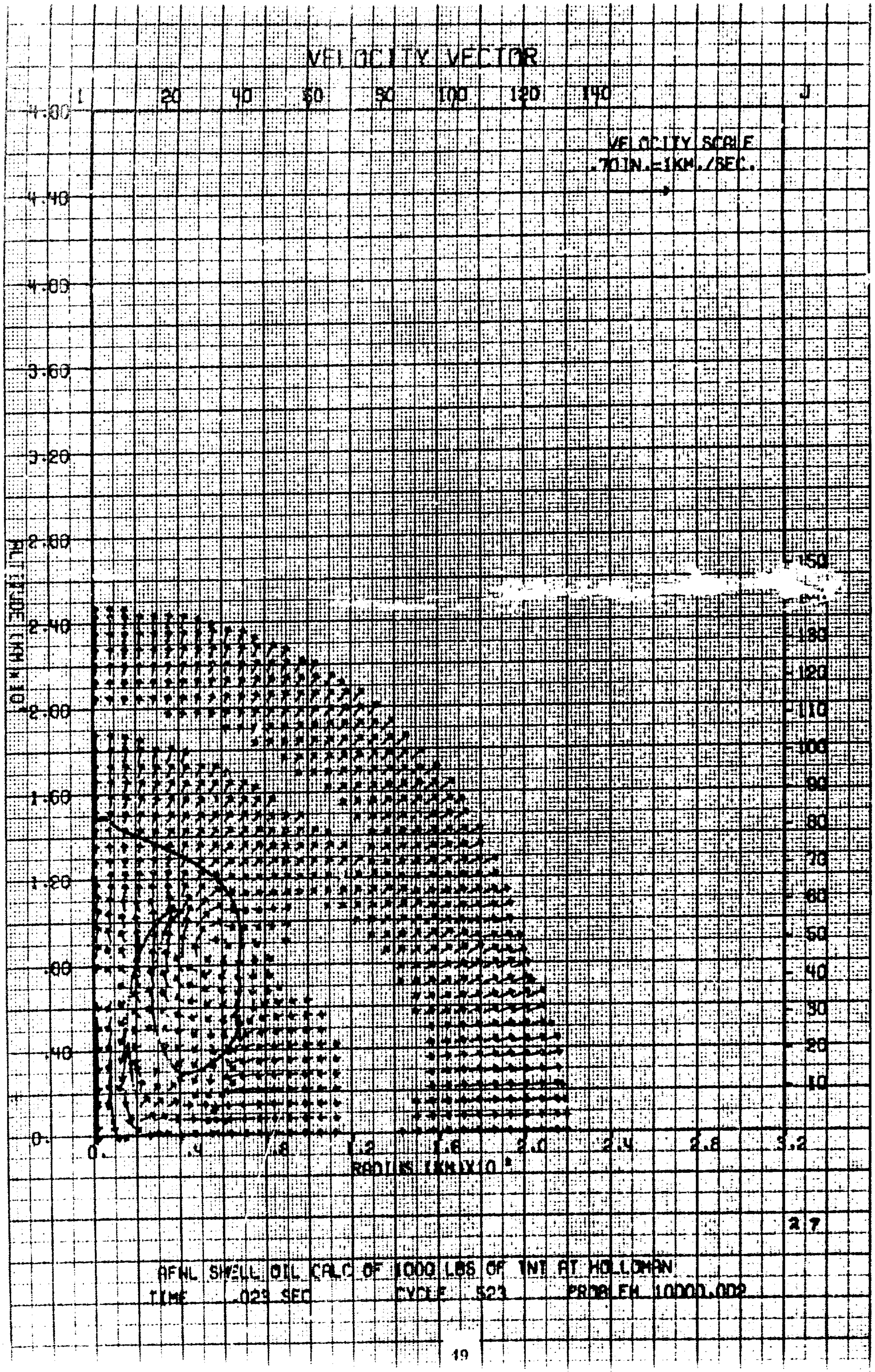


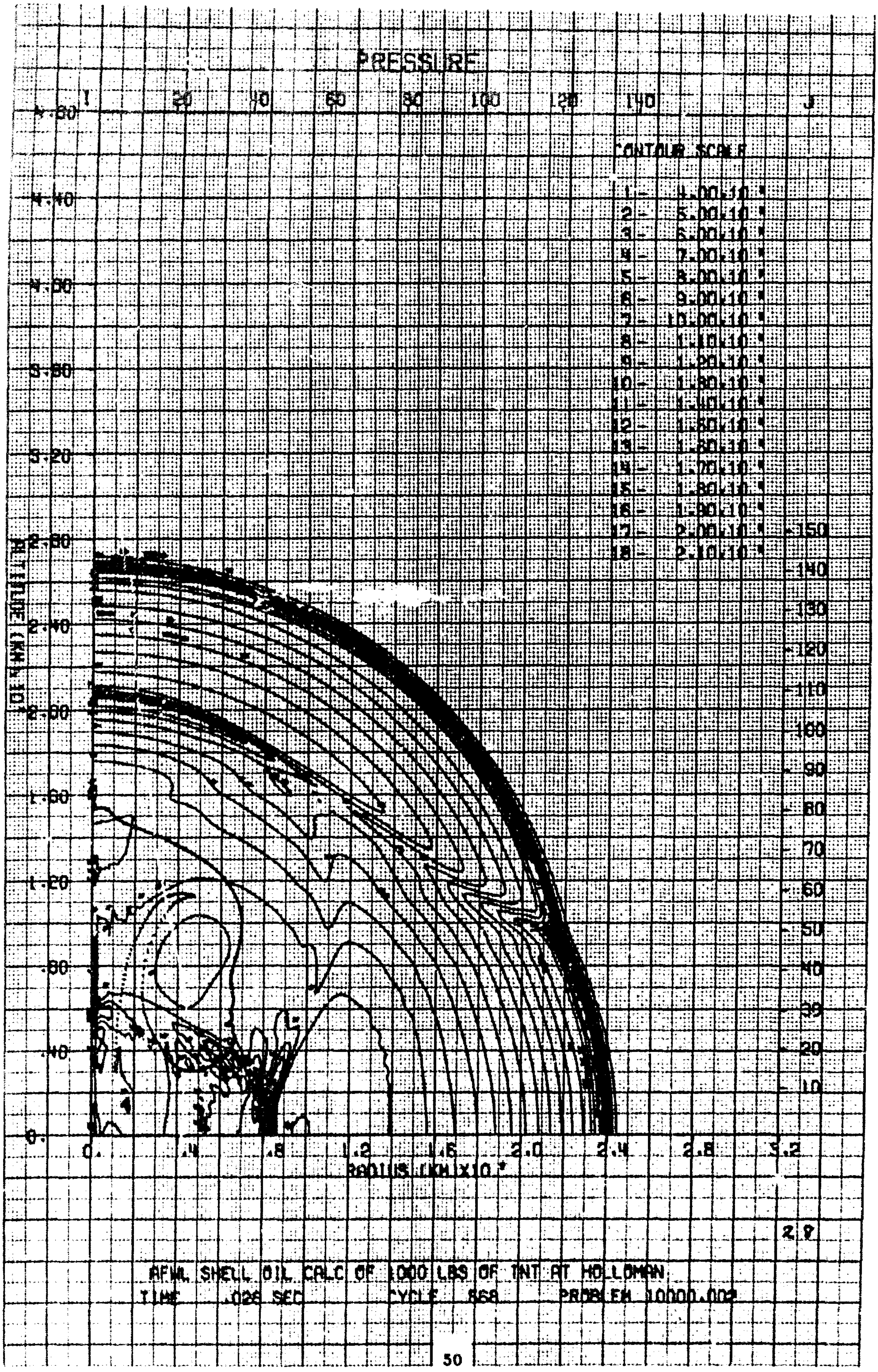
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN

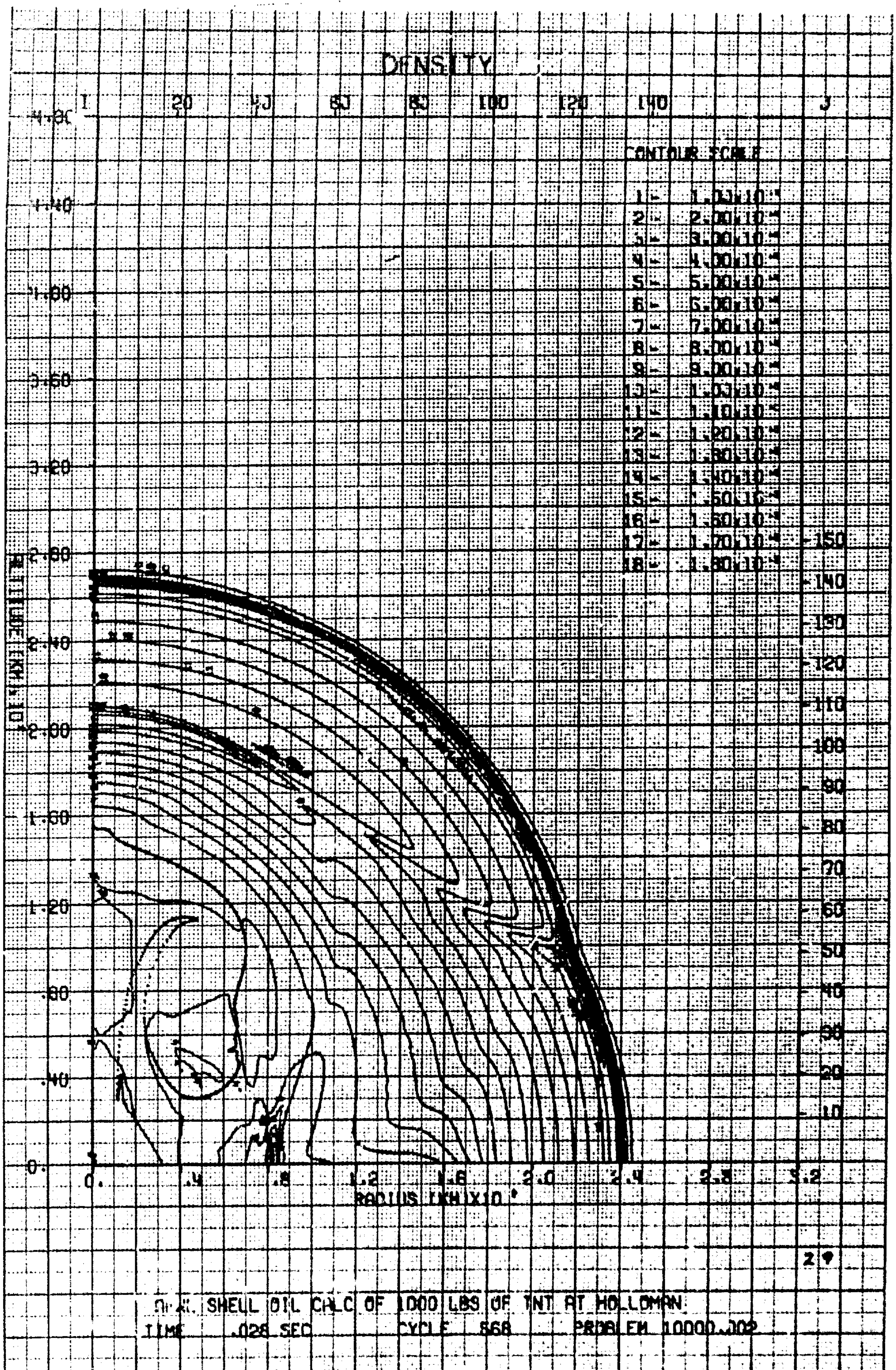
TIME .020 SEC CYCLE 392 PROBLEM 10000.002

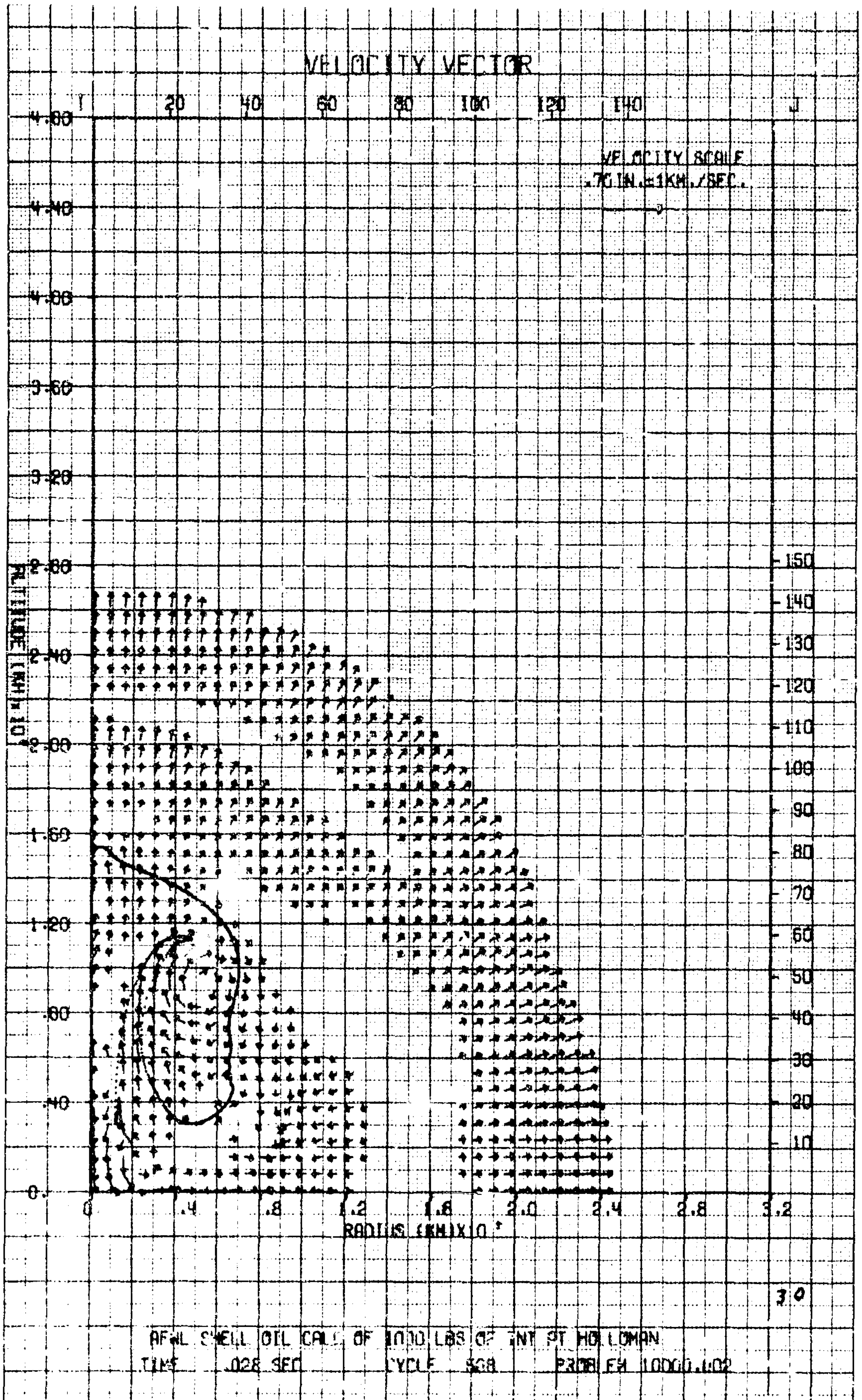

PRESSURE
CONTOUR SCALE
1 - -2.00x10
2 - 0. x10
3 - 2.00x10
4 - 4.00x10
5 - 6.00x10
6 - 8.00x10
7 - 10.00x10
8 - 1.20x10
9 - 1.40x10
10 - 1.60x10
11 - 1.80x10
12 - 2.00x10
13 - 2.20x10
14 - 2.40x10
ALTITUDE (KM) x10
RADIUS (KM) x10
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .023 SEC CYCLE 523 PROBLEM 10000.002
25


DENSITY
CONTOUR SCALE
1 - 2.00x10
2 - 3.00x10
3 - 4.00x10
4 - 5.00x10
5 - 6.00x10
6 - 7.00x10
7 - 8.00x10
8 - 9.00x10
9 - 1.00x10
10 - 1.10x10
11 - 1.20x10
12 - 1.30x10
13 - 1.40x10
14 - 1.50x10
15 - 1.60x10
16 - 1.70x10
17 - 1.80x10
18 - 1.90x10
19 - 2.00x10
RADIUS (KM)X10
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .023 SEC CYCLE 523 PROBLEM 10000.002

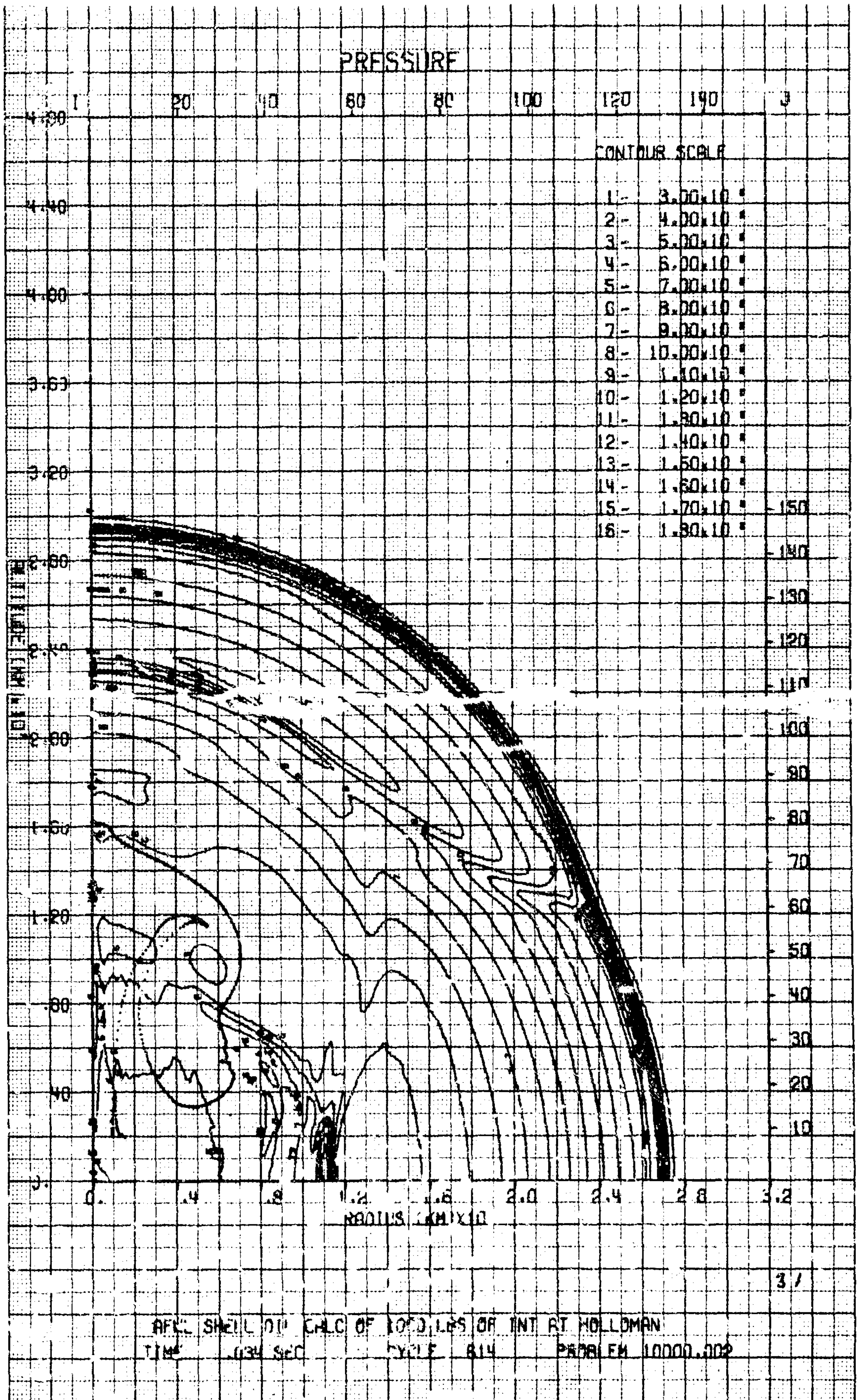

VELOCITY VECTOR
I
20
40
60
80
100
120
140
J
VELOCITY SCALE
.70 IN.=1KM./SEC.
ALTITUDE (KM X10)
RADIUS (KM)X10
0.
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
27
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .023 SEC CYCLE 523 PROBLEM 10000.002

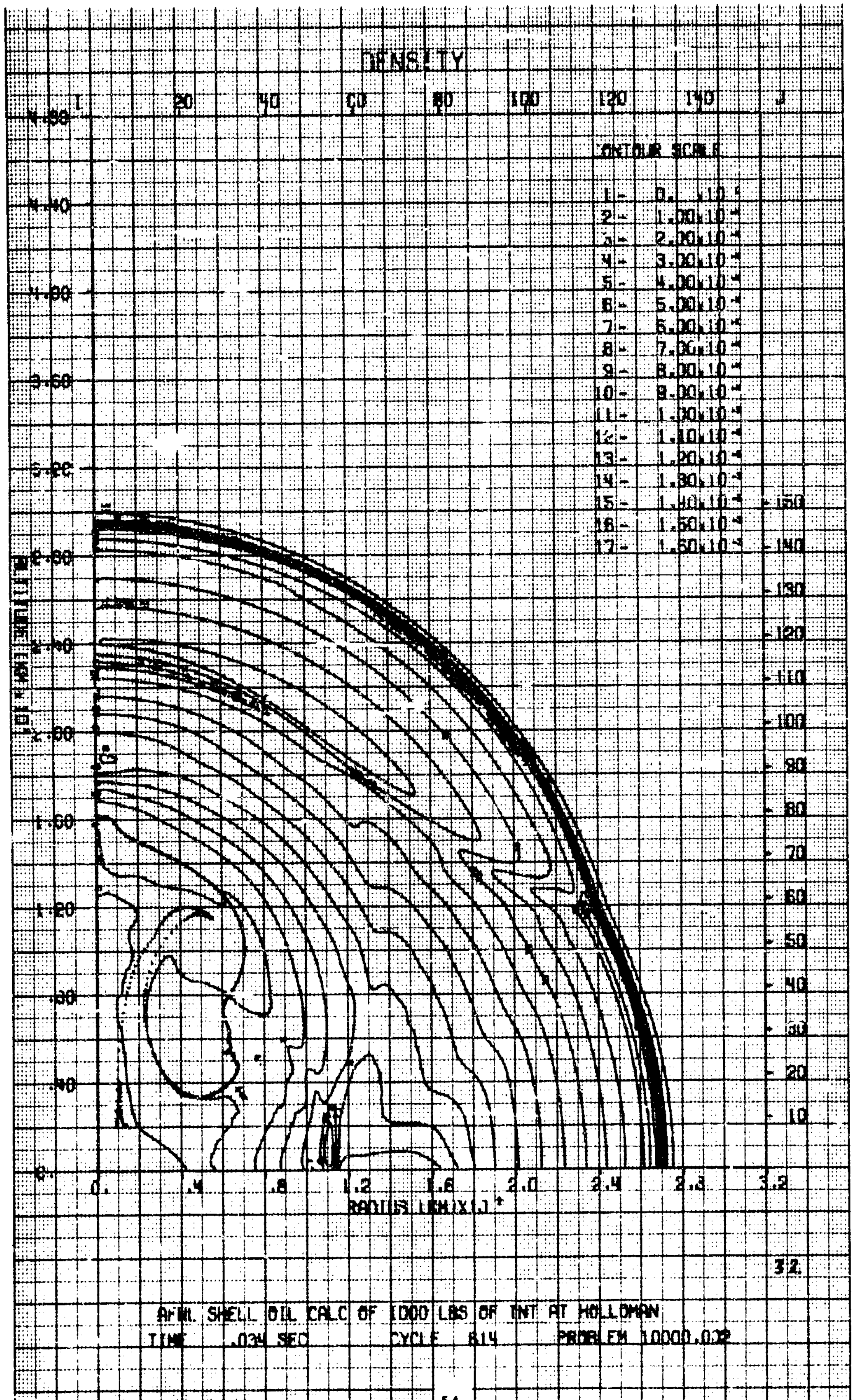

PRESSURE
CONTOUR SCALE
ALTITUDE (KM X 10)
RADIUS (KM X 10)
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .026 SEC CYCLE 868 PROBLEM 10000.002

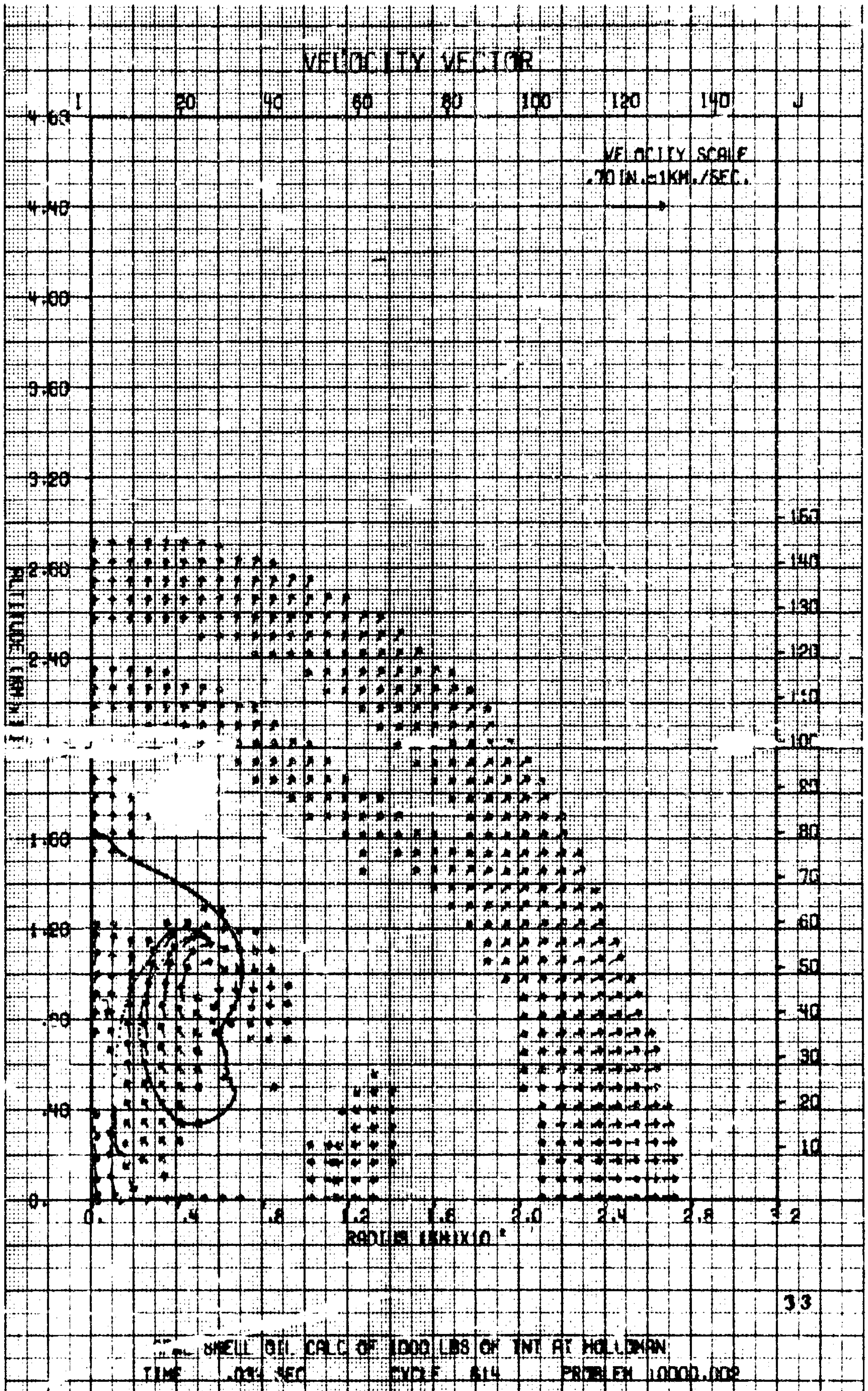

DENSITY
CONTOUR SCALE
RADIUS (KM X10¹)
ALTITUDE (KM X10¹)
A.F.W.L. SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .028 SEC CYCLE 868 PROBLEM 10000.002

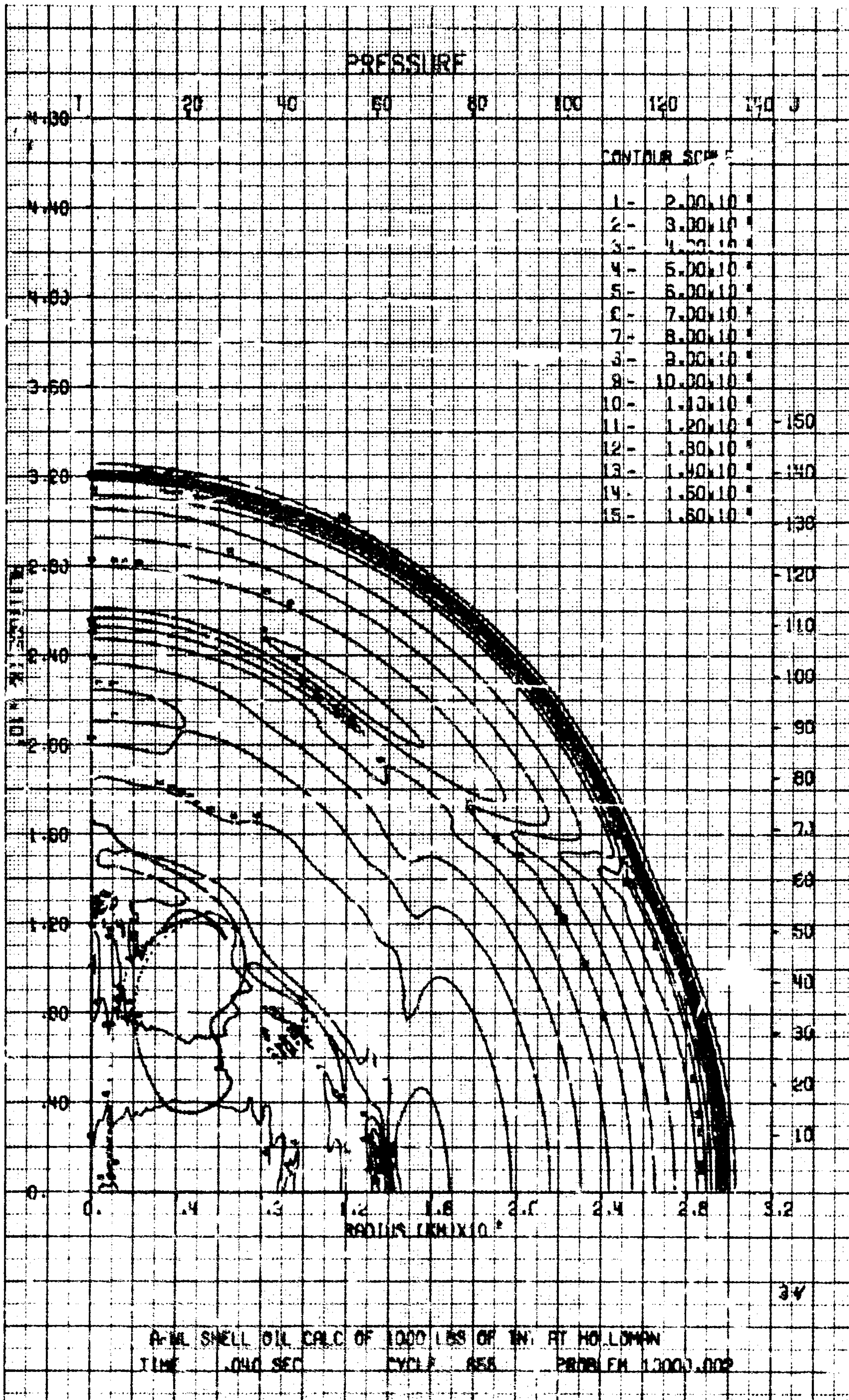


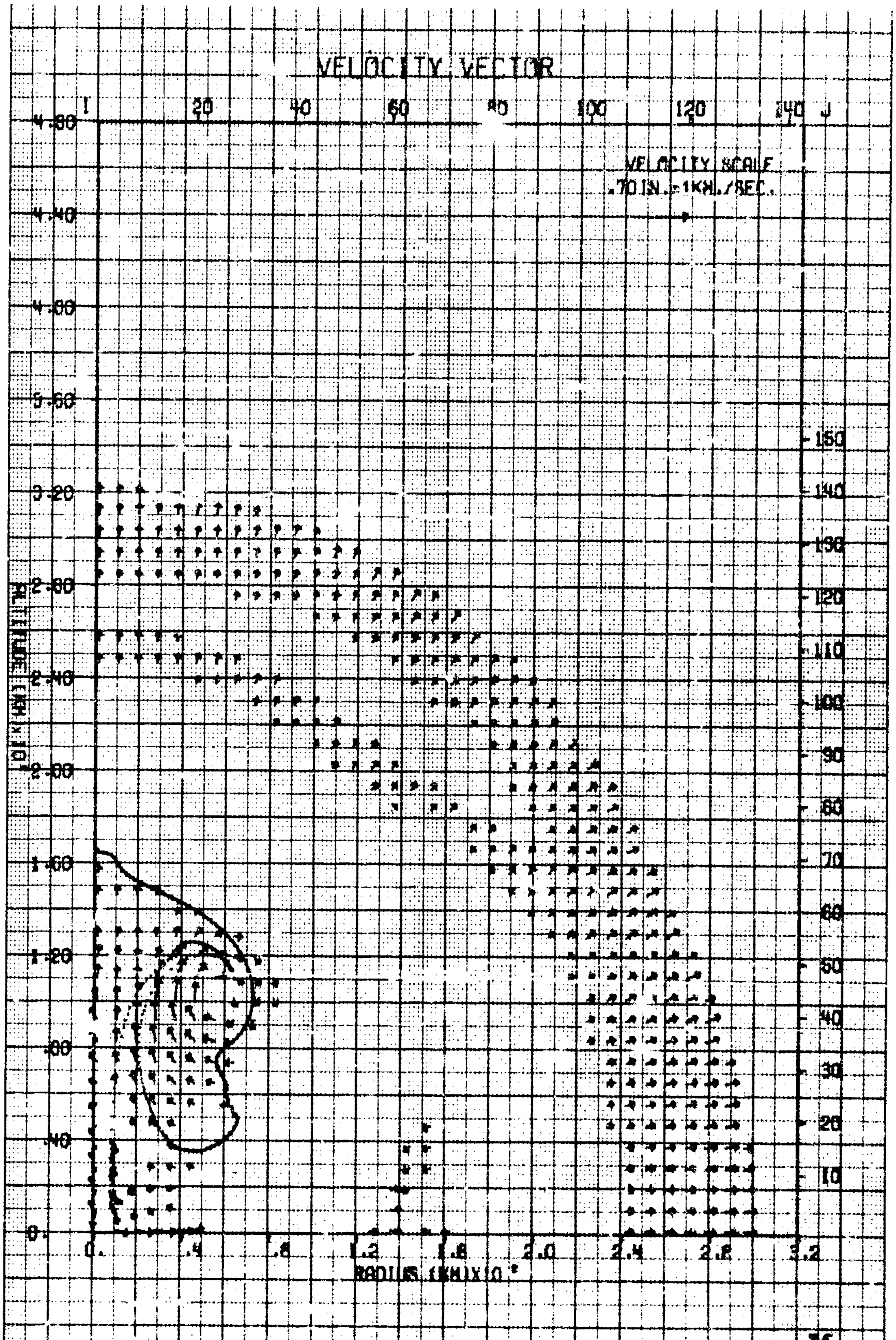
VELOCITY VECTOR
I
20
40
60
80
100
120
140
J
VELOCITY SCALE
.75 IN.=1KM./SEC.
4.80
4.40
4.00
3.60
3.20
2.80
2.40
2.00
1.60
1.20
.80
.40
0.
ALTITUDE (KM)x10
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
RADIUS (KM)X10
30
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .028 SEC
CYCLE
PROBLEM


PRESSURE
CONTOUR SCALE
RADIUS (KM)X10
AFCL SHELL DIP CALC OF 10(?) LBS OF INT AT HOLLOMAN
TIME .034 SEC
CYCLE 814
PROBLEM 10000.002

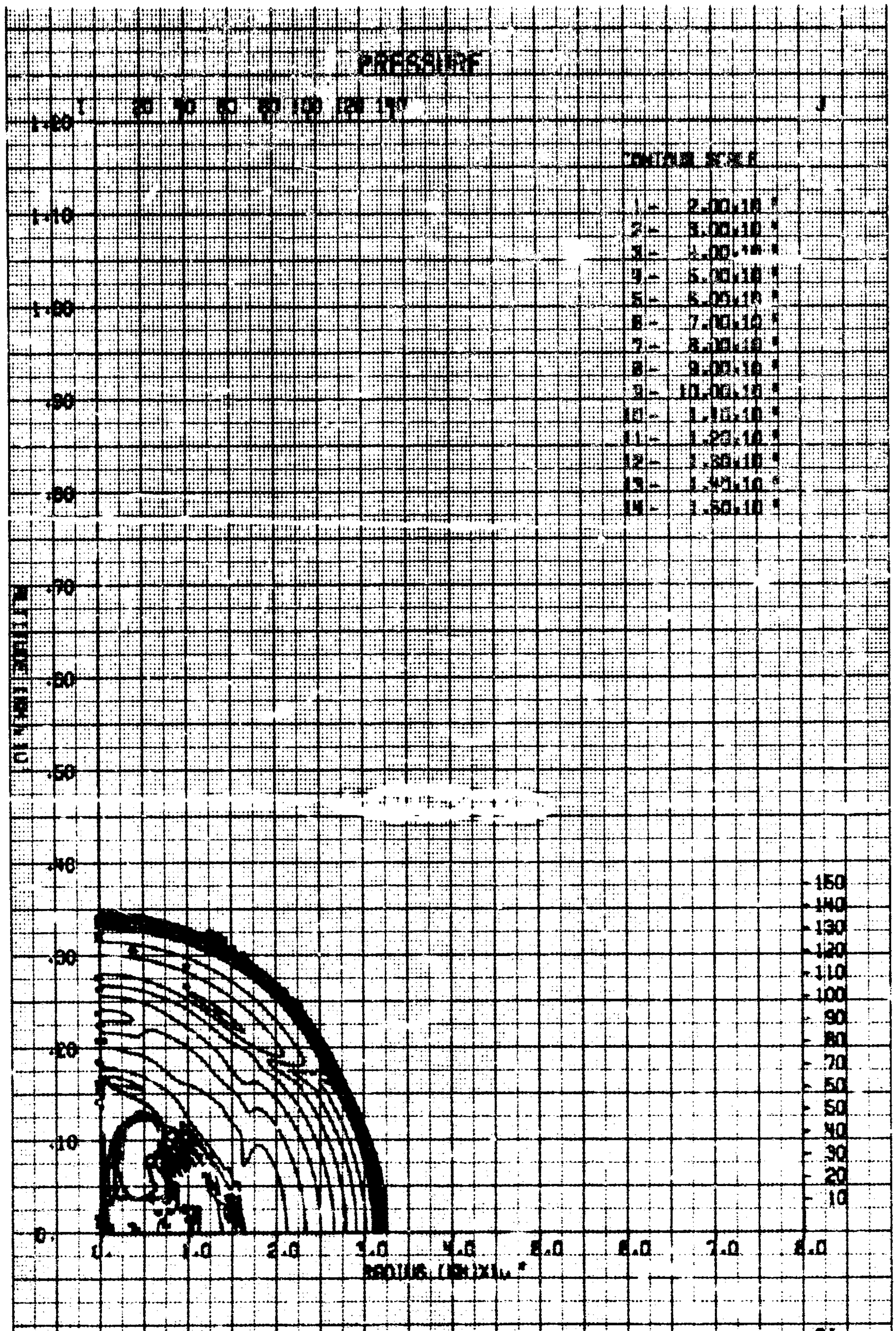

DENSITY
CONTOUR SCALE
1 - 0. x10⁻⁵
2 - 1.00x10⁻⁴
3 - 2.00x10⁻⁴
4 - 3.00x10⁻⁴
5 - 4.00x10⁻⁴
6 - 5.00x10⁻⁴
7 - 6.00x10⁻⁴
8 - 7.00x10⁻⁴
9 - 8.00x10⁻⁴
10 - 9.00x10⁻⁴
11 - 1.00x10⁻³
12 - 1.10x10⁻³
13 - 1.20x10⁻³
14 - 1.30x10⁻³
15 - 1.40x10⁻³
16 - 1.50x10⁻³
17 - 1.60x10⁻³
RADIUS (CM)(X1.)
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .034 SEC CYCLE 814 PROBLEM 10000.032
32


VELOCITY VECTOR
VELOCITY SCALE
.70 IN.=1KM./SEC.
ALTITUDE (KM)
RADIUS (KM)X10
SHELL BIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .034 SEC CYCLE 614 PROBLEM 10000.002
33

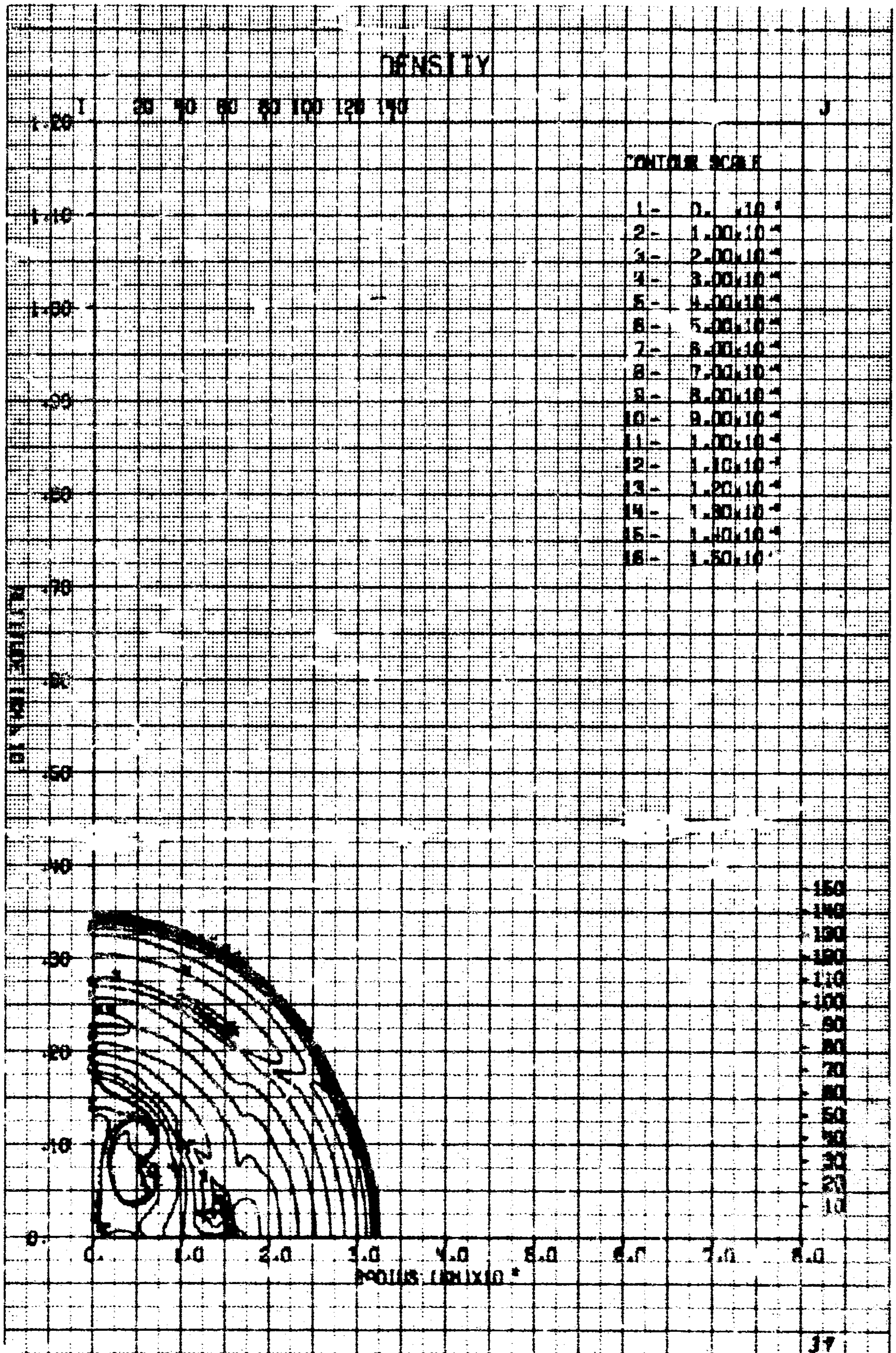

PRESSURE
CONTOUR SCALE
1- 2.00x10
2- 3.00x10
4- 5.00x10
5- 6.00x10
7- 8.00x10
9- 10.00x10
11- 1.20x10
12- 1.30x10
13- 1.40x10
14- 1.50x10
15- 1.60x10
RADIUS (KM)X10
A-NL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .040 SEC CYCLE 858 PROBLEM 1000.002



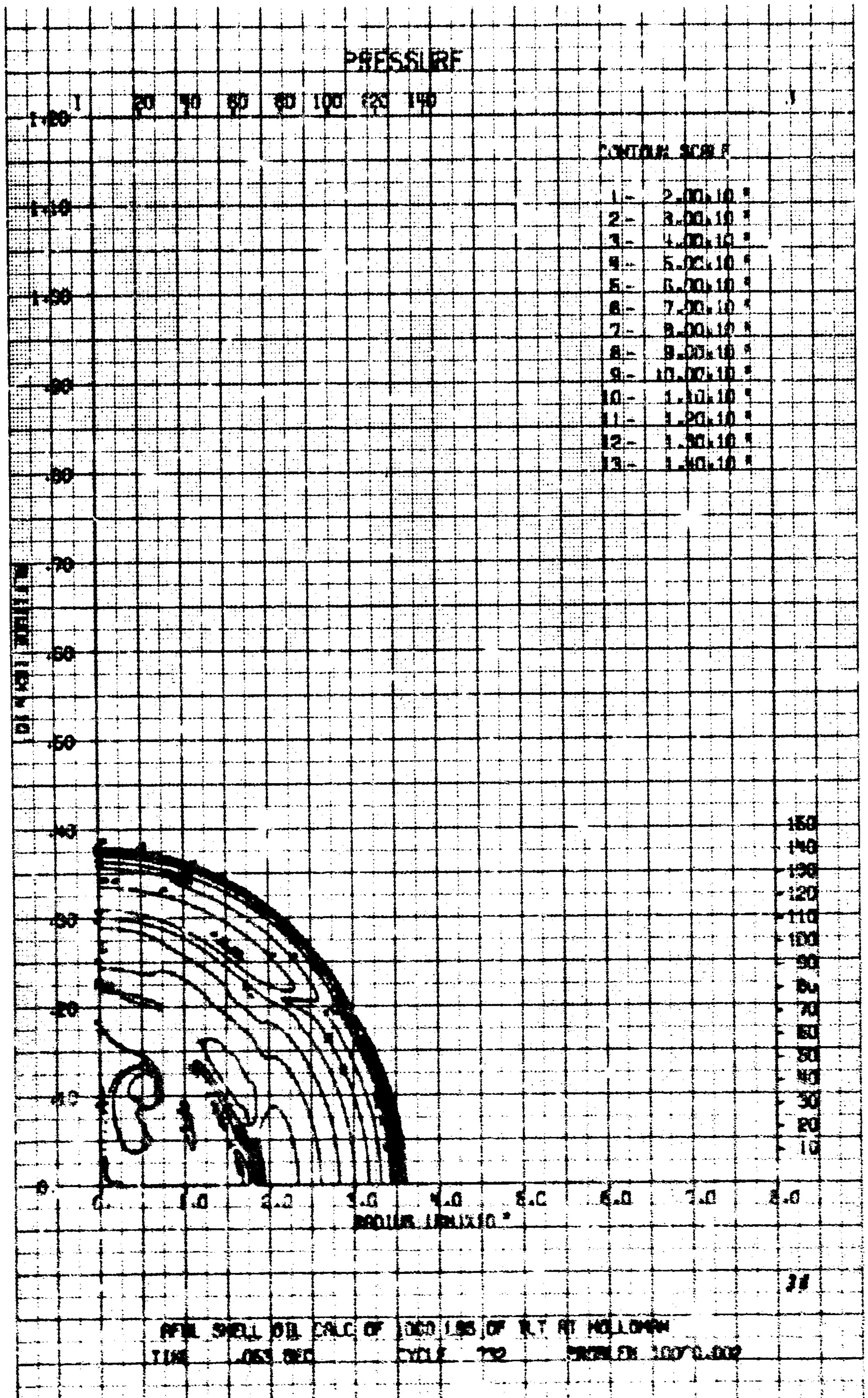
AFWL SHELL OIL CALC OF 1000 LBS OF TNT AT HOLLOW
TIME .040 SEC CYCLE 885 PROBLEM 10000.002

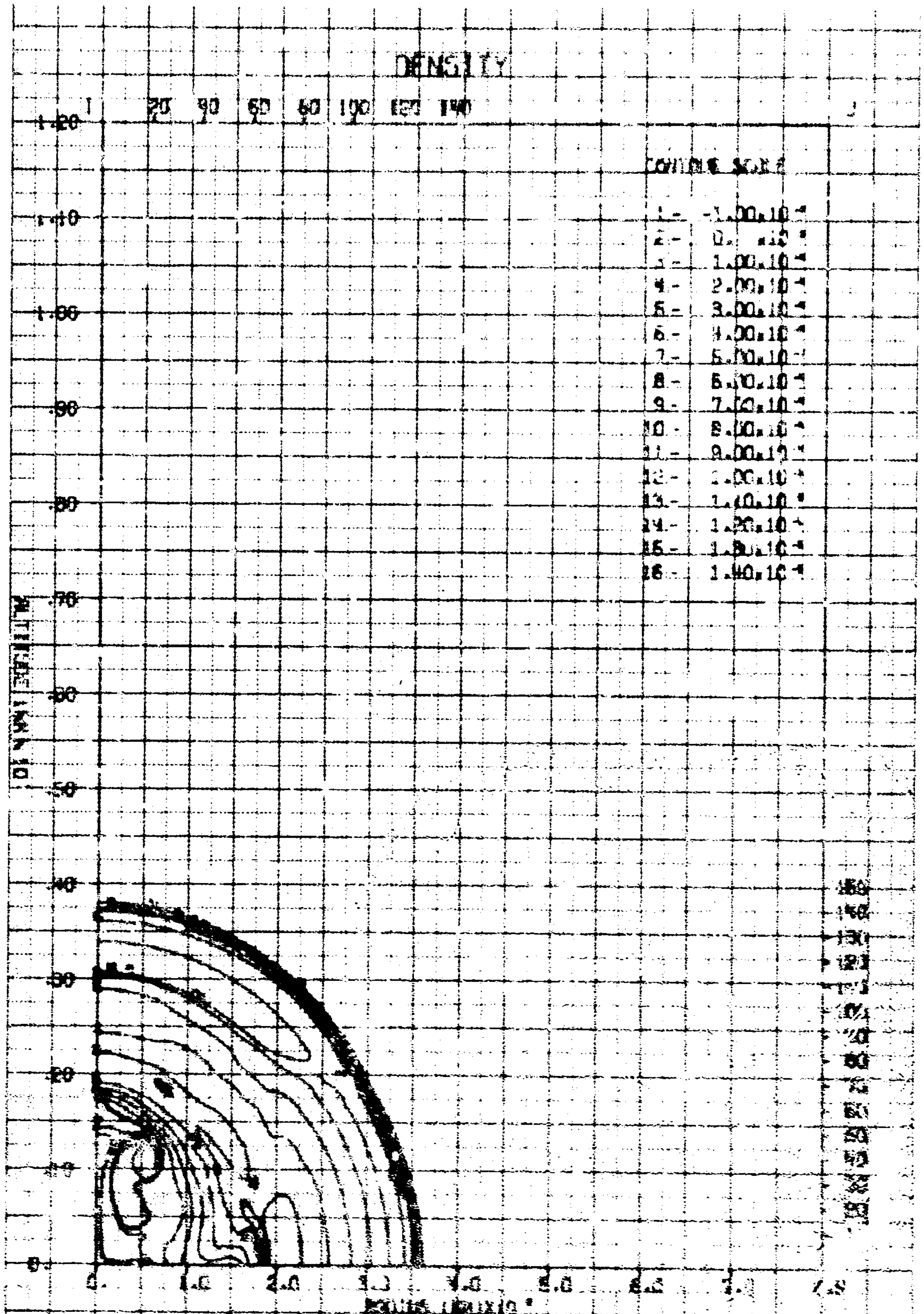


AFWL SHELL 3D. CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .048 SEC CYCLE 886 PROB FN 10000.002



AFWL SHELL 2DL CALC OF 1000 LBS OF TNT AT HOLLOMAN
TIME .045 SEC CYCLE 888 PROBLEM 10000.002


PRESSURE
20 40 60 80 100 120 140
CONTOUR SCALE
1 - 2.00 10
2 - 3.00 10
3 - 4.00 10
4 - 5.00 10
5 - 6.00 10
6 - 7.00 10
7 - 8.00 10
8 - 9.00 10
9 - 10.00 10
10 - 1.10 10
11 - 1.20 10
12 - 1.30 10
13 - 1.40 10
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0
CYCLE 732



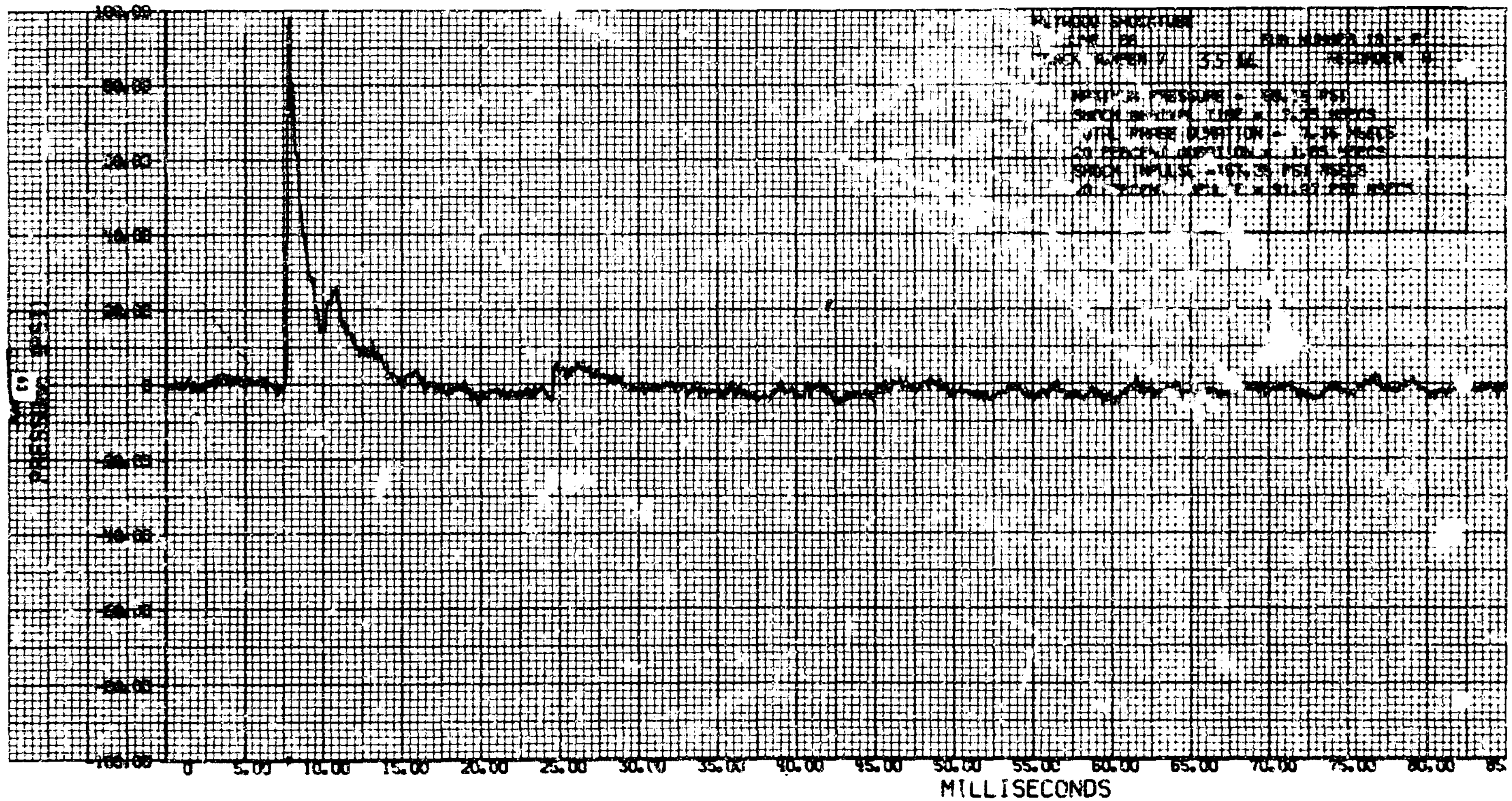
[illegible]
TIME .063 SEC CYCLE 132 [illegible]

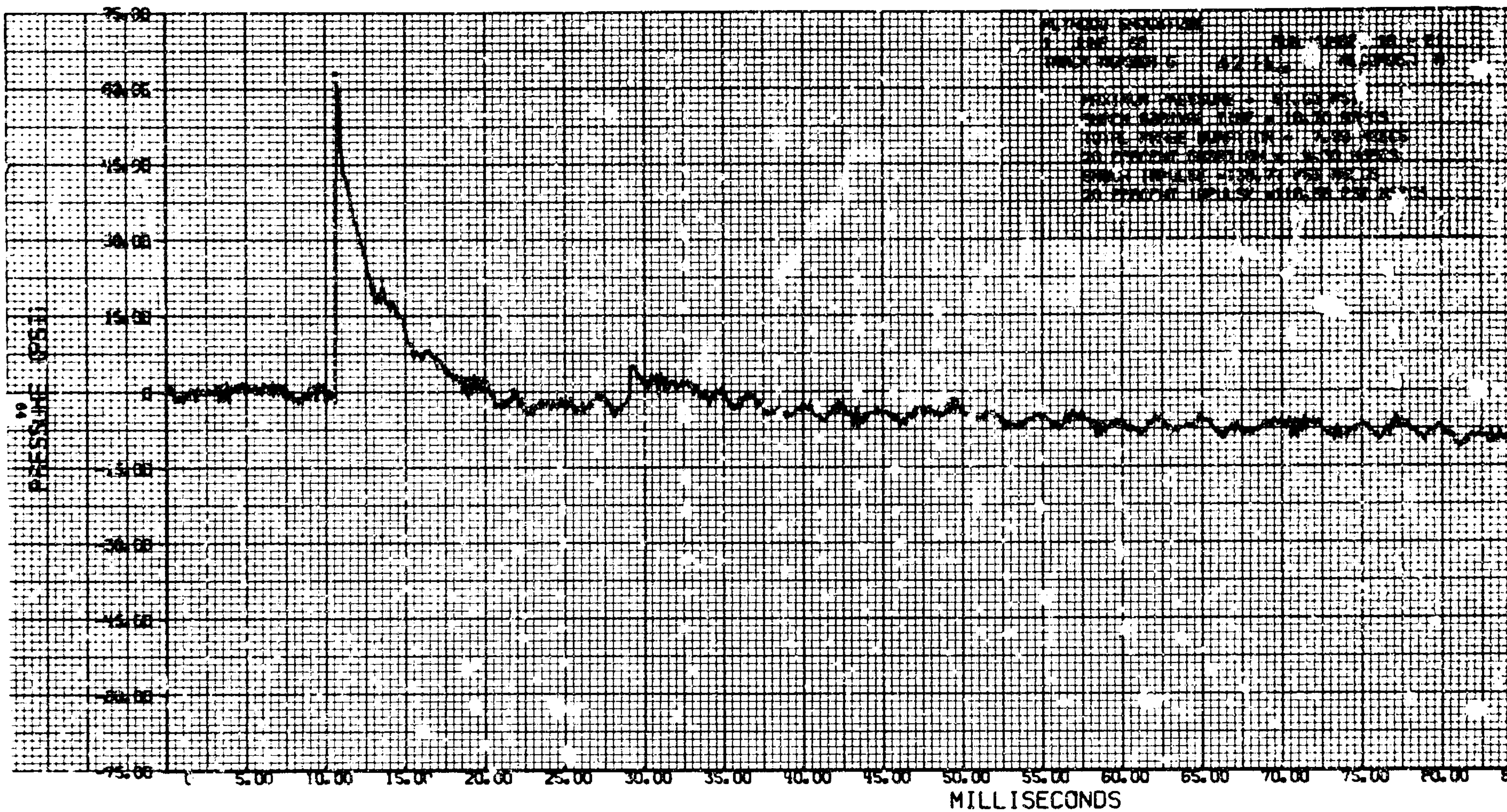
Appendix II

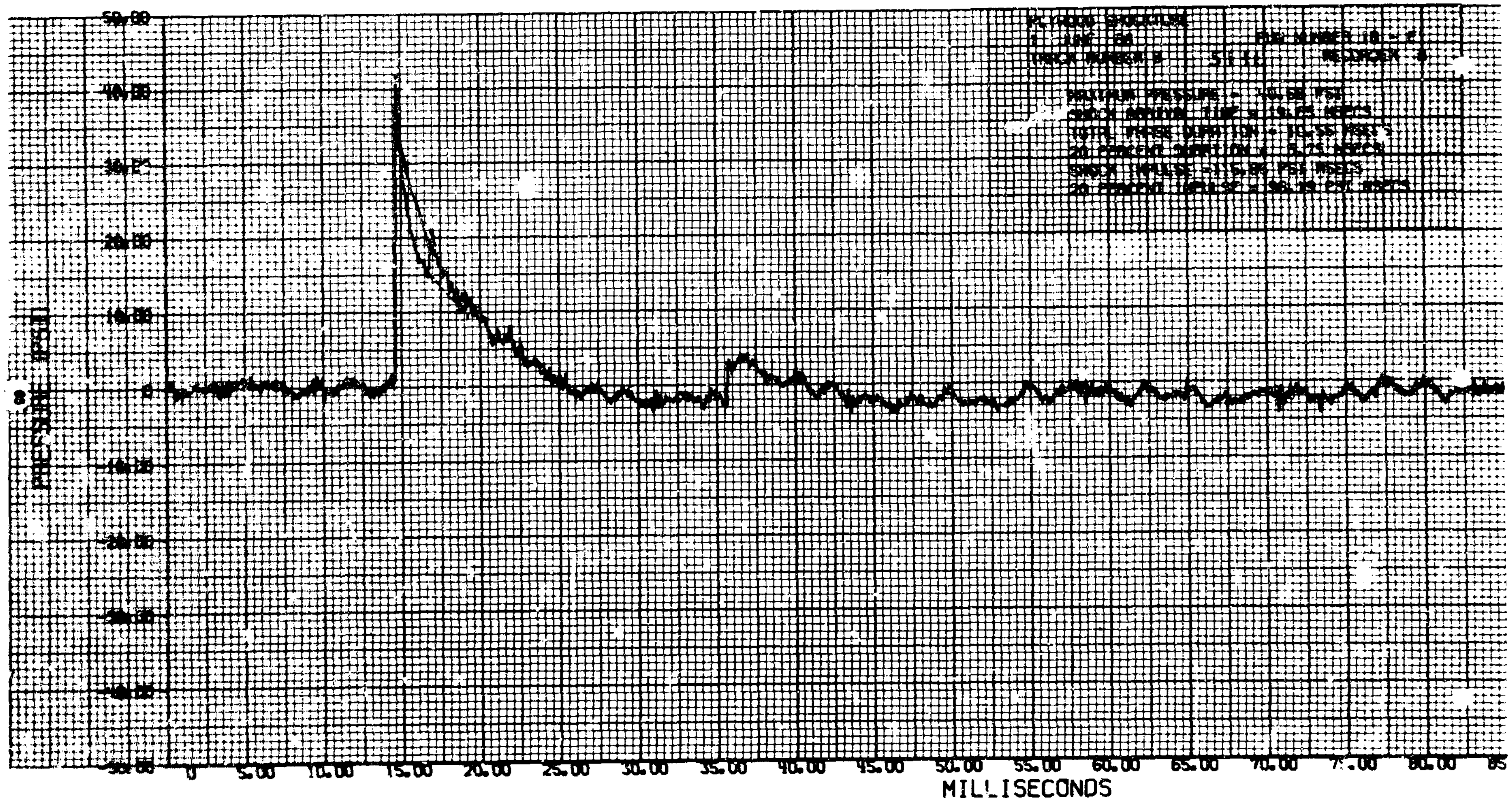
STATION 1 TO 11 PLOTS

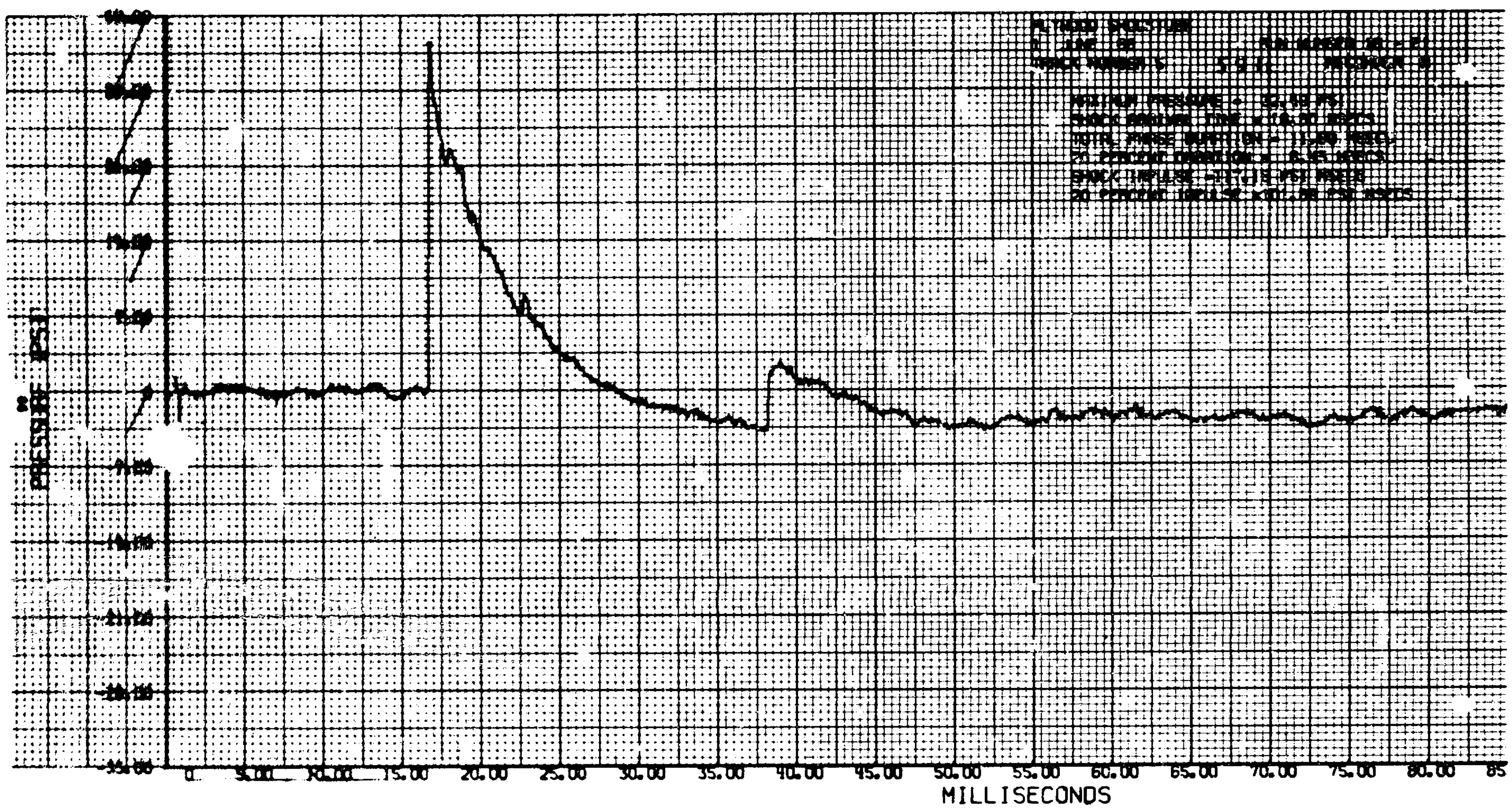
This appendix includes the experimental overpressure vs. time curves at the eleven test stations and the computed curves taken at the same positions as at the experimental stations. Computed curves include overpressure, two components of dynamic pressure, the corresponding impulses, and the two components of velocity.

This appendix presents the most consistent comparison of experiment and calculation. A summary of this comparison is found in figures 6 and 7 of the text.

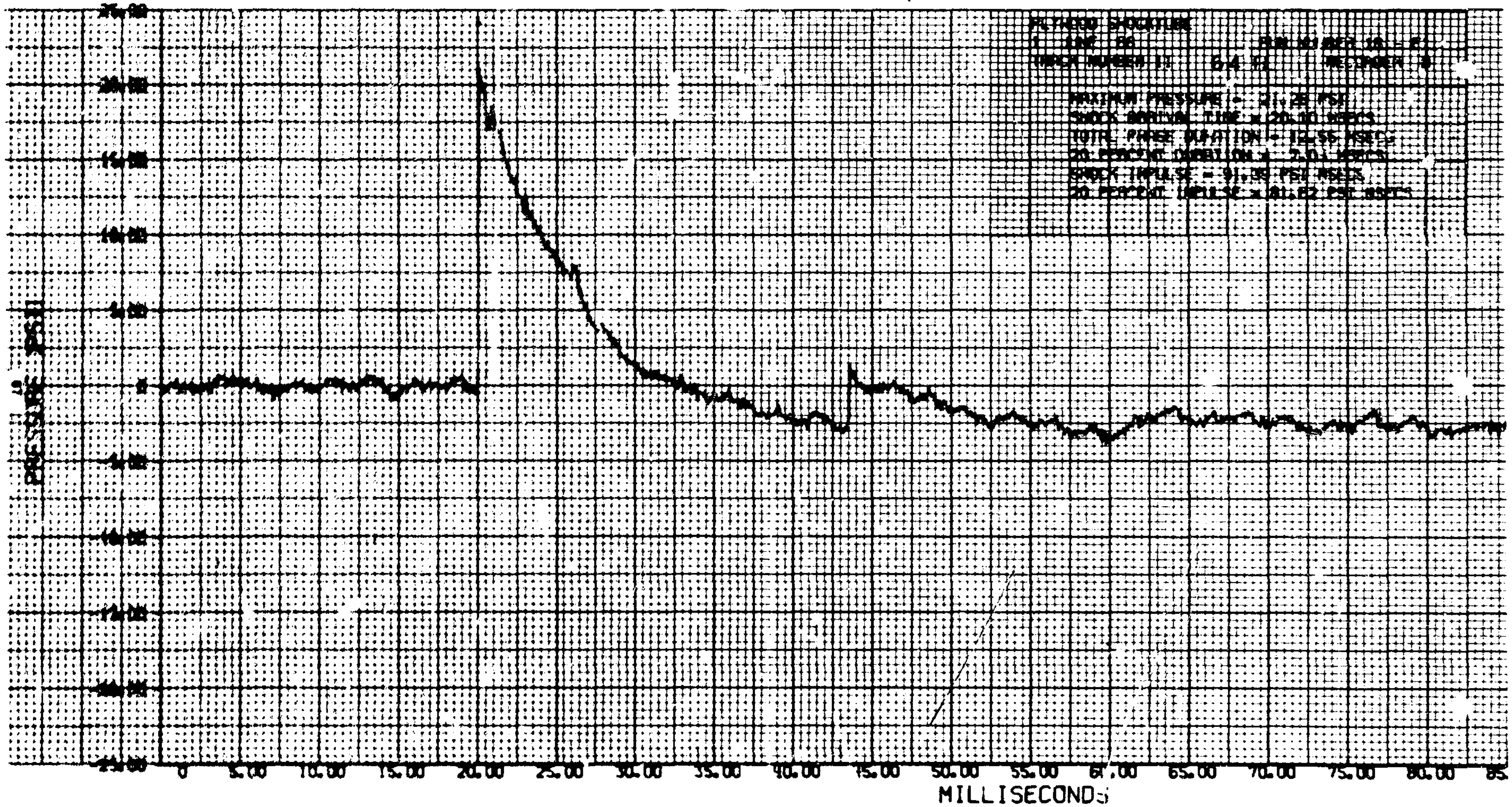

PRESSURE (PSI)
100.00
80.00
60.00
40.00
20.00
0
-20.00
-40.00
-60.00
-80.00
-100.00
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85
MILLISECONDS

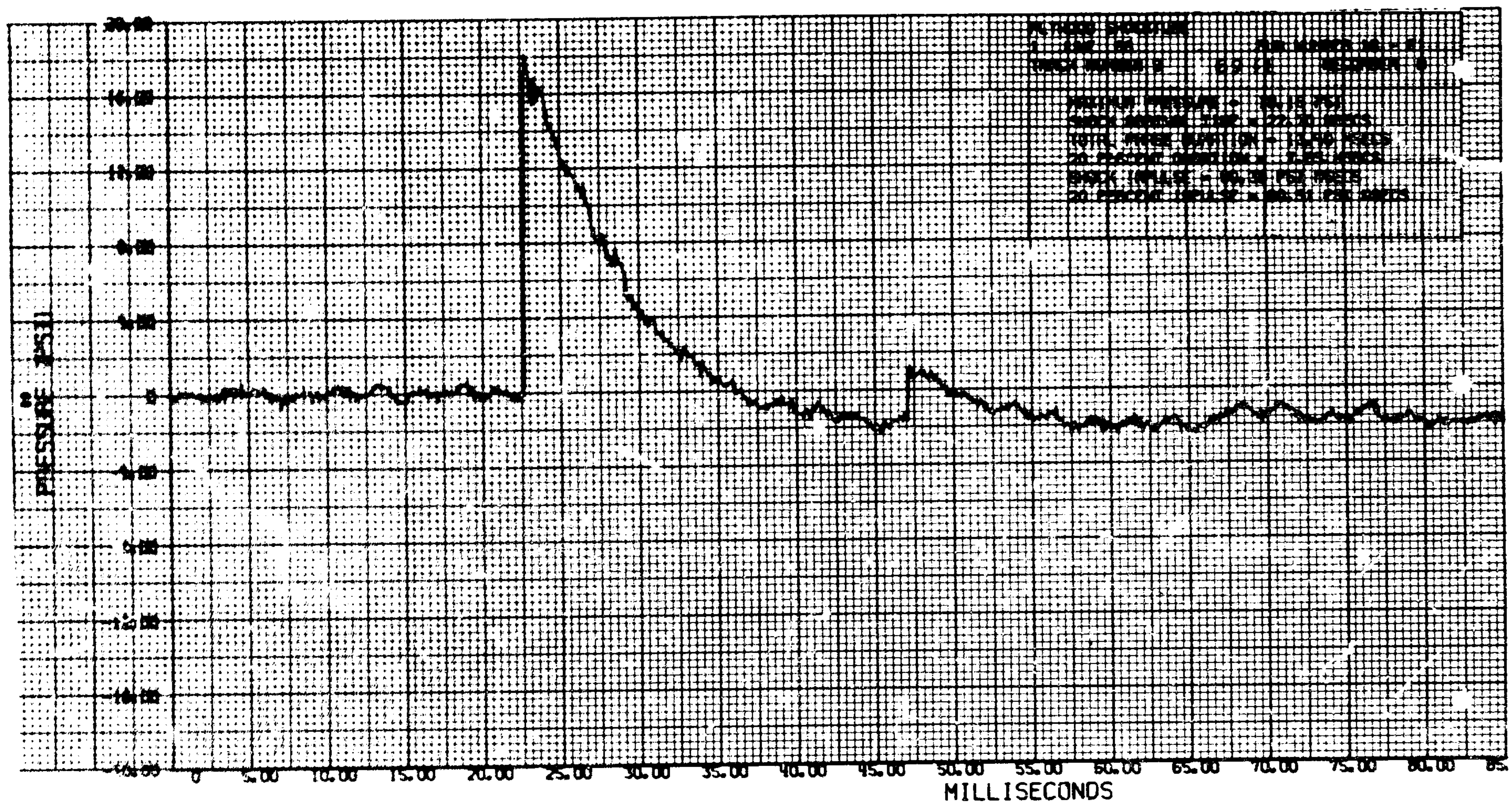

PRESSURE (PSI)
75.00
60.00
45.00
30.00
15.00
0
-15.00
-30.00
-45.00
-60.00
-75.00
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85
MILLISECONDS


50.00
40.00
30.00
20.00
10.00
0
-10.00
-20.00
-30.00
-40.00
-50.00
PRESSURE (PSI)
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
80.00
85
MILLISECONDS

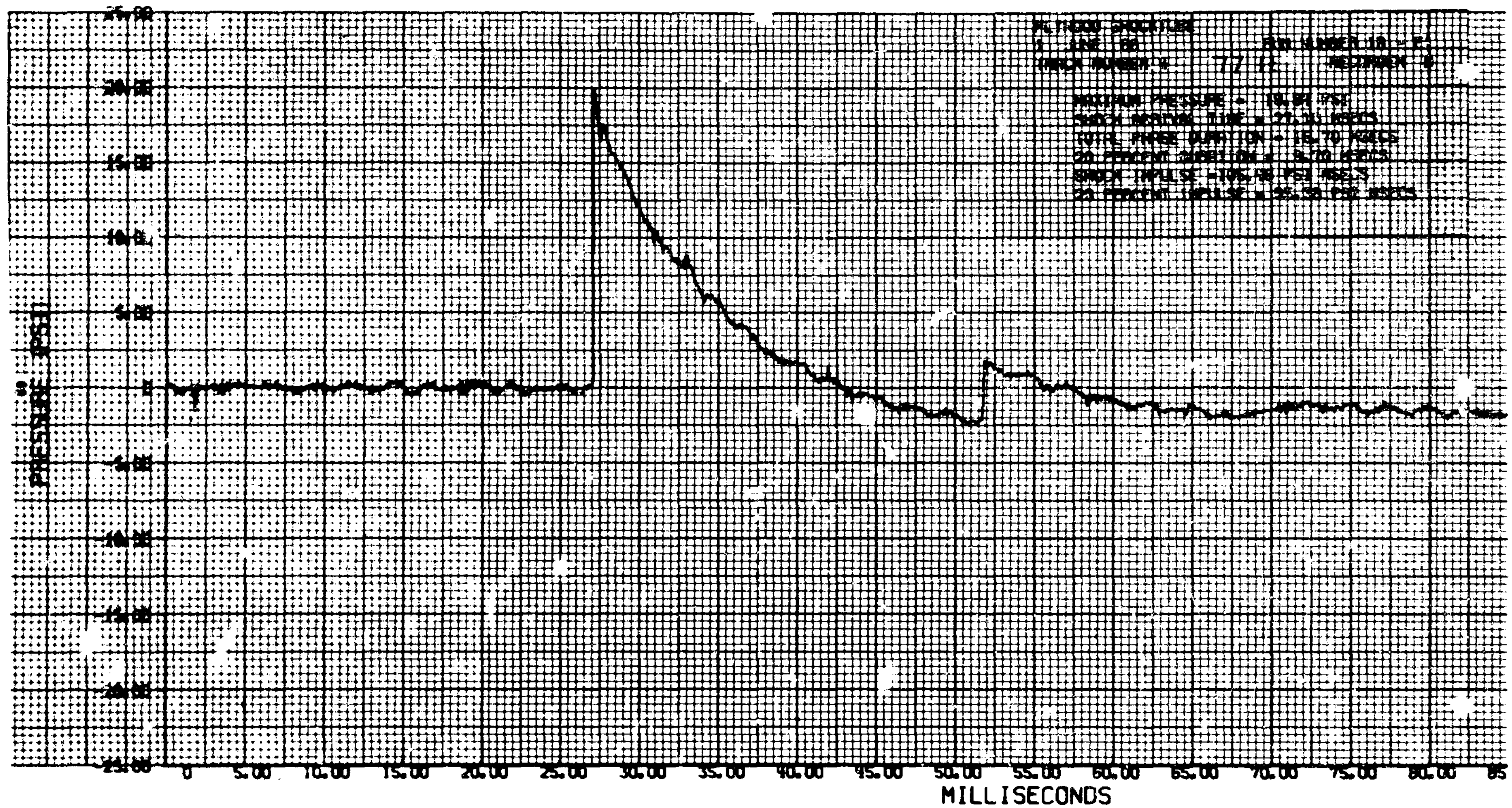


PRESSURE (PSI)
MILLISECONDS
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85

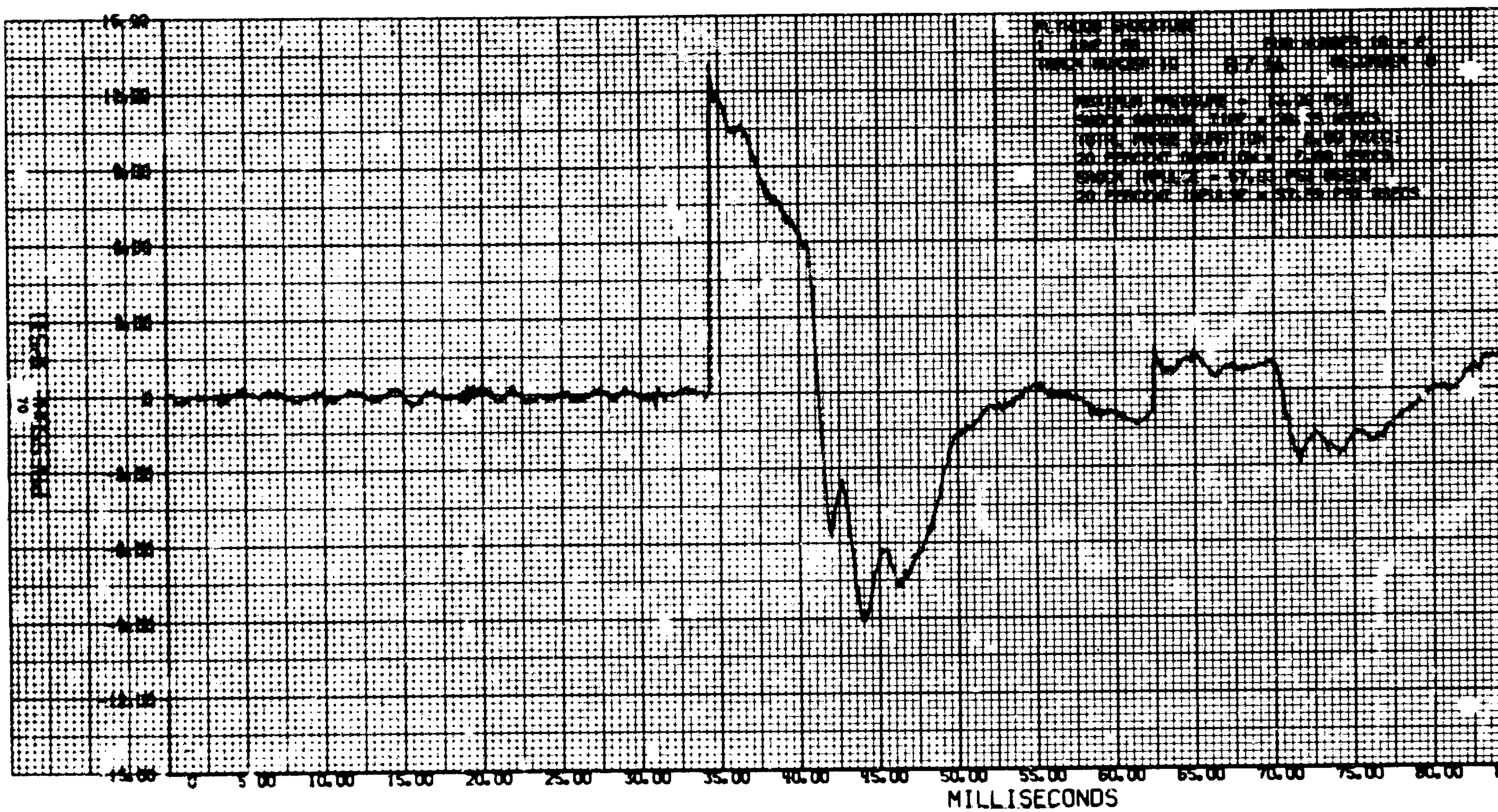

0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85
MILLISECONDS



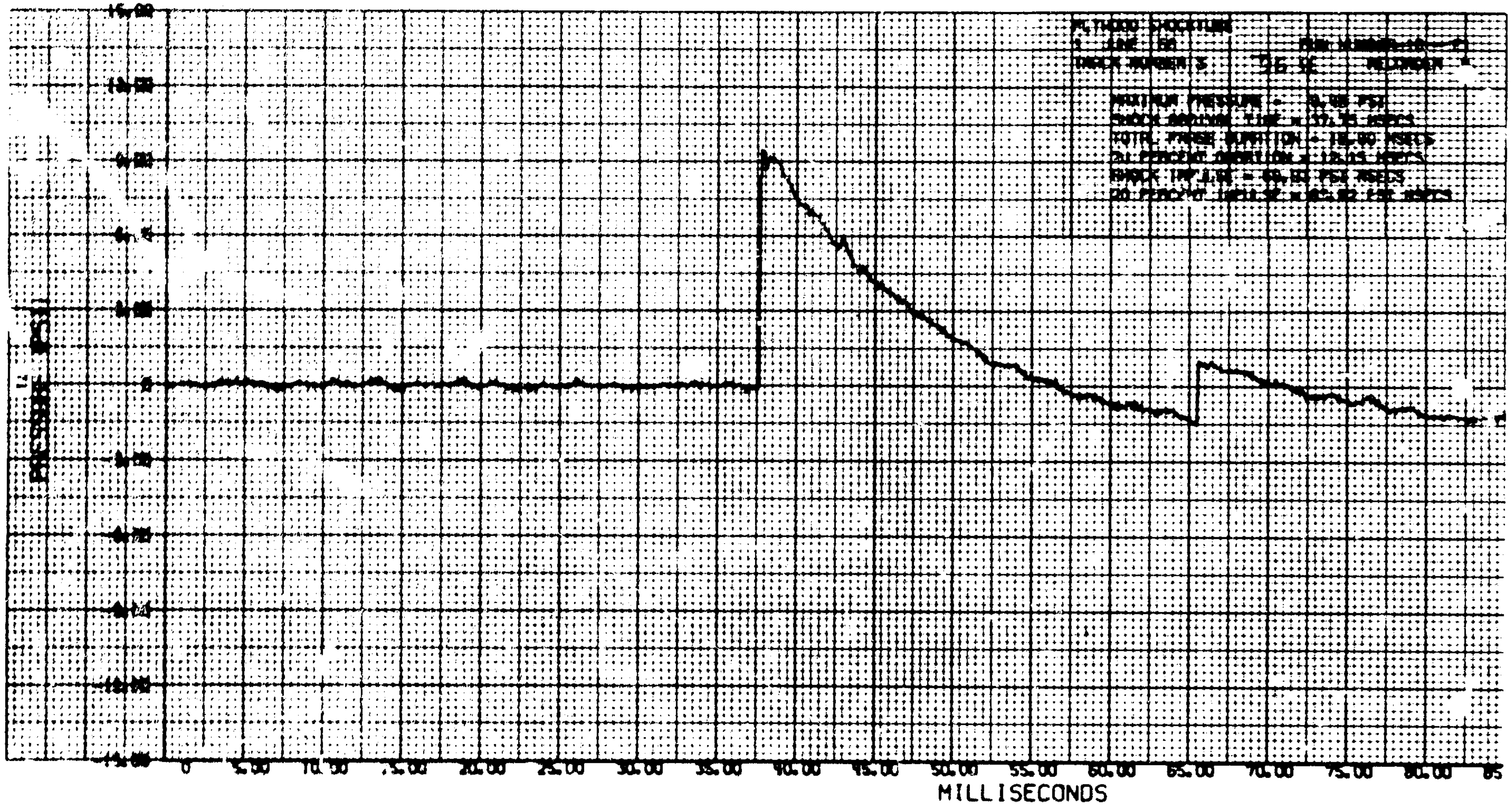
PRESSURE (PSI)
MILLISECONDS
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00



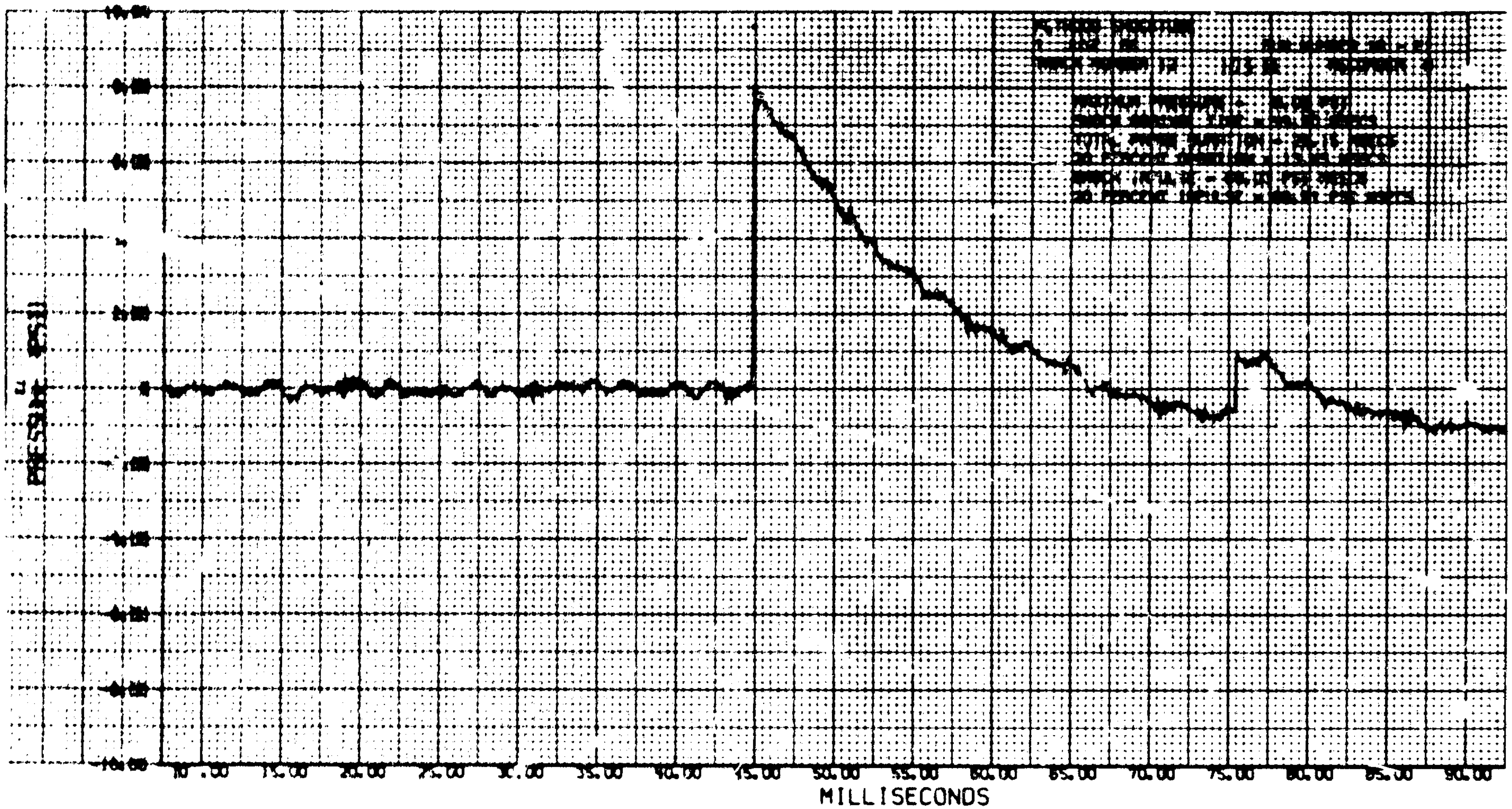
PRESSURE (PSI)
25.00
20.00
15.00
10.00
5.00
0
-5.00
-10.00
-15.00
-20.00
-25.00
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85
MILLISECONDS

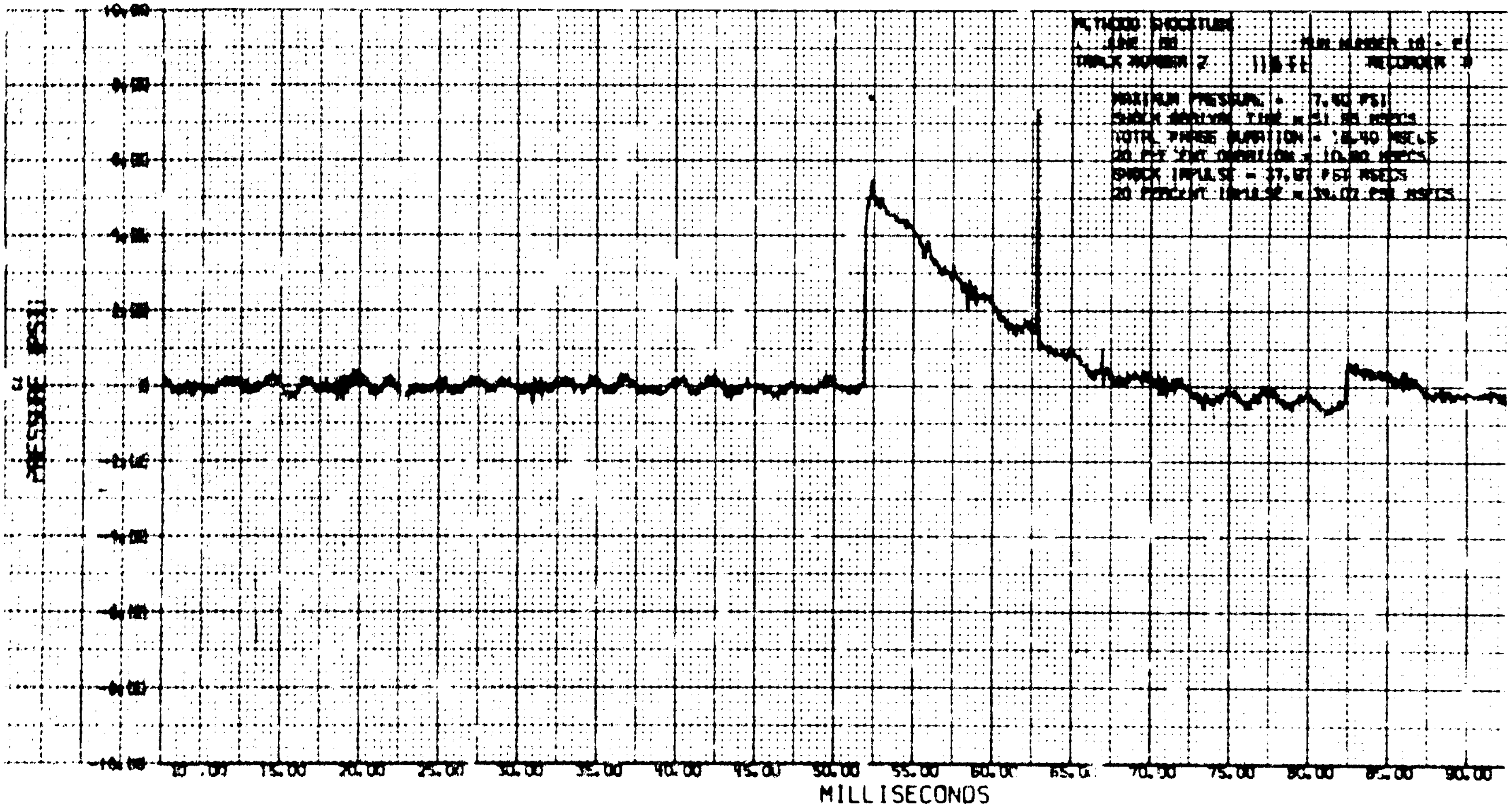


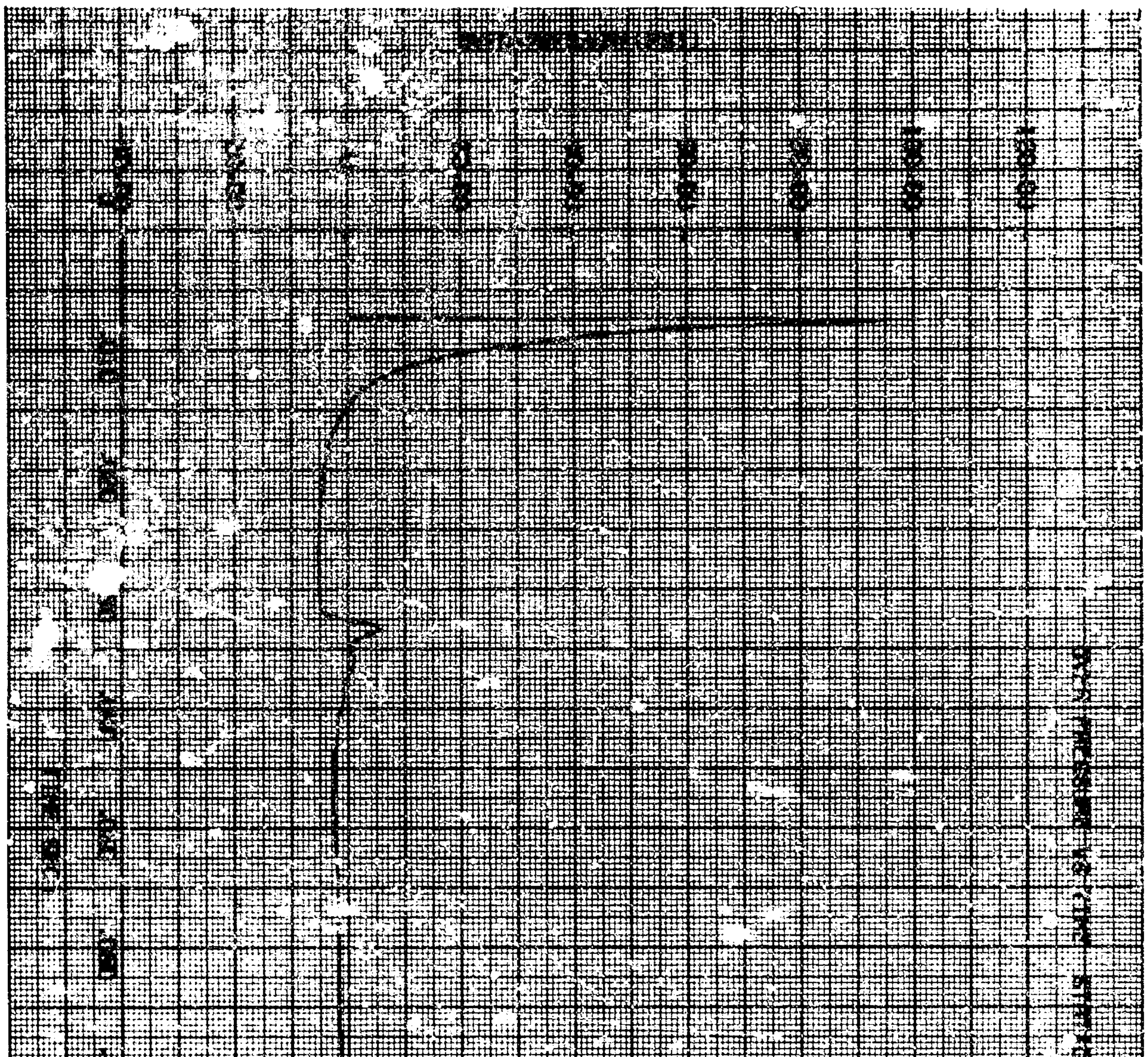
0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85
MILLISECONDS

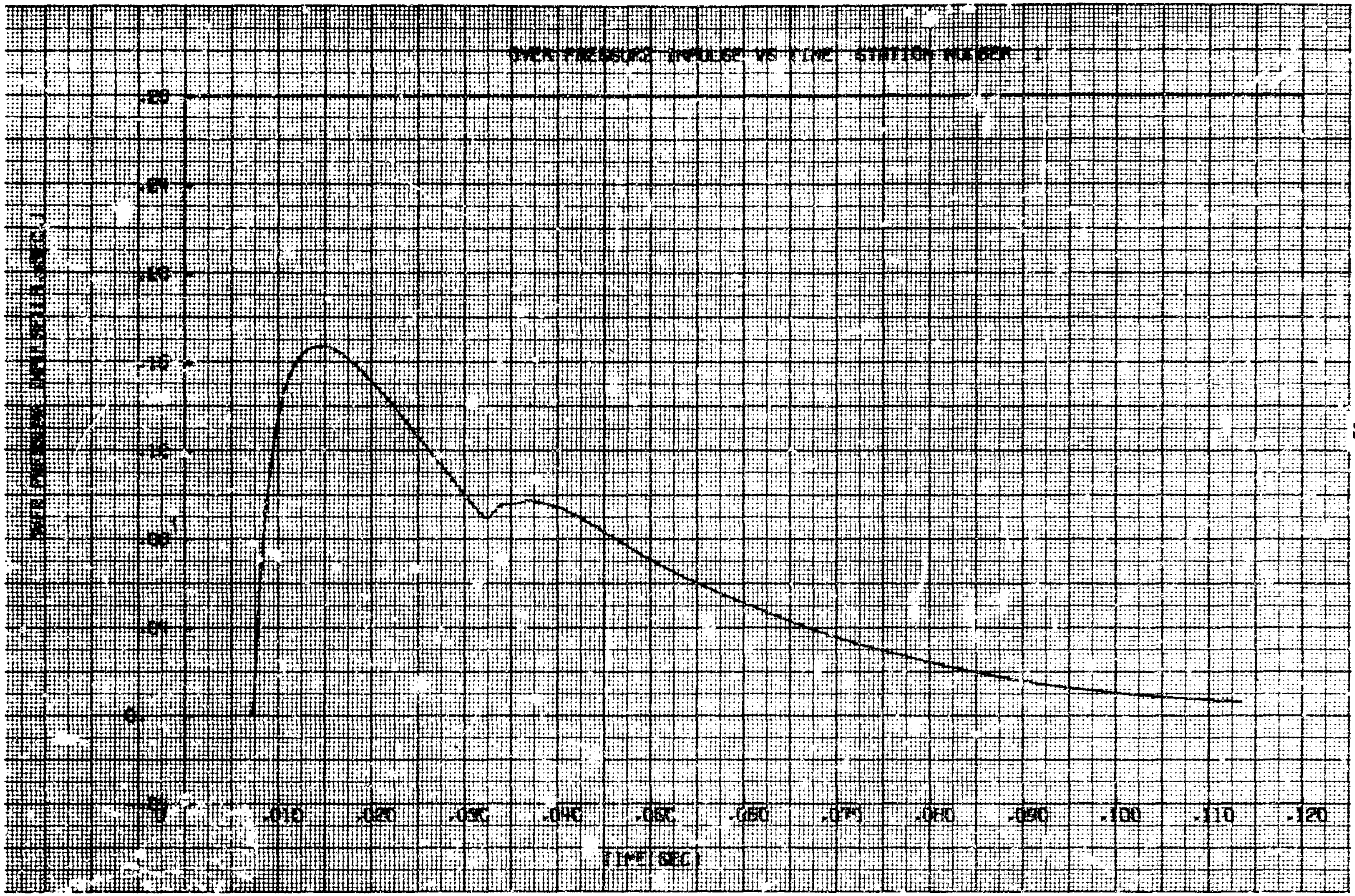


MILLISECONDS

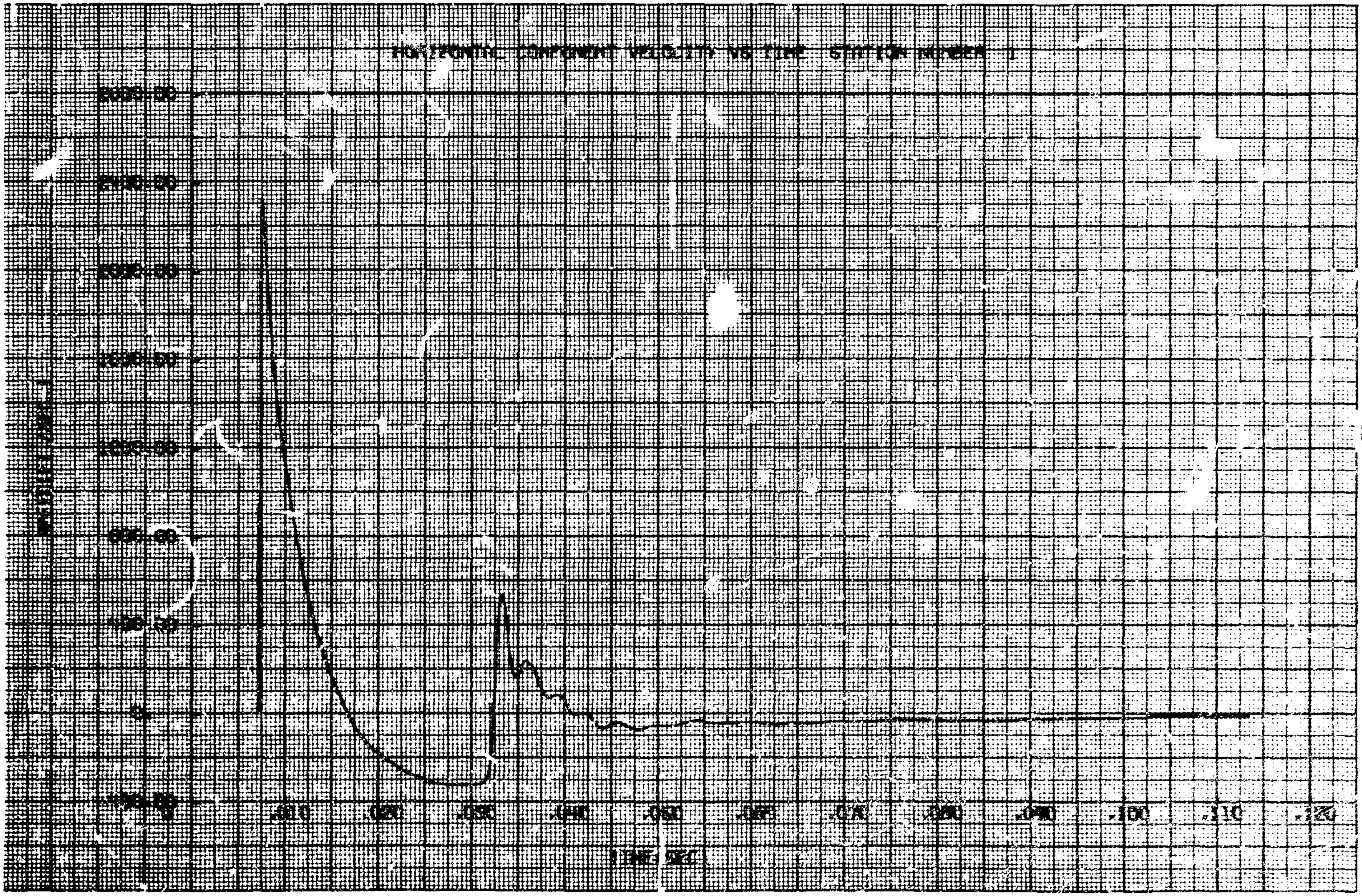

PRESSURE (PSI)
MILLISECONDS
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85.00
90.00

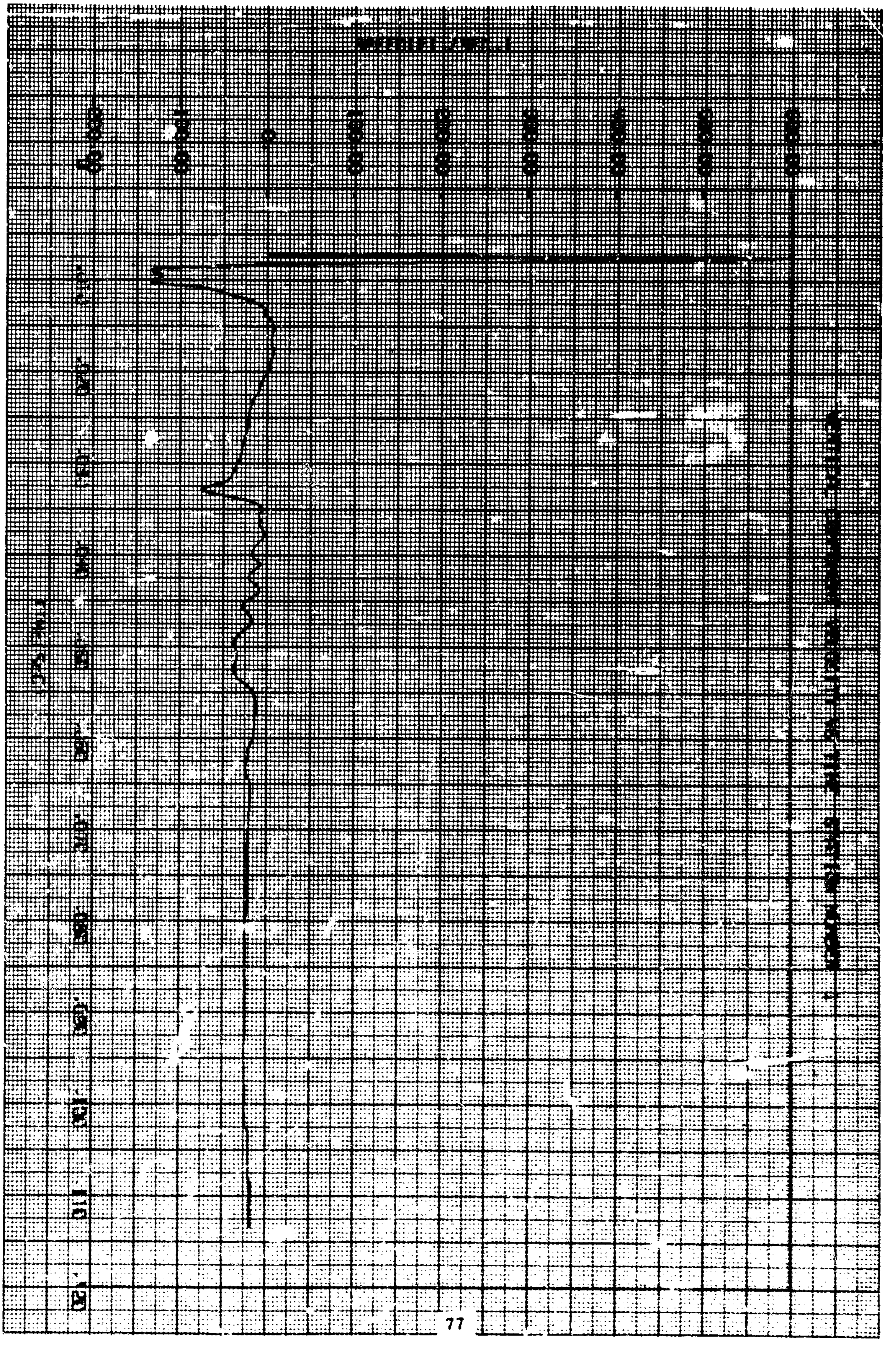

PRESSURE (PSI)
MILLISECONDS

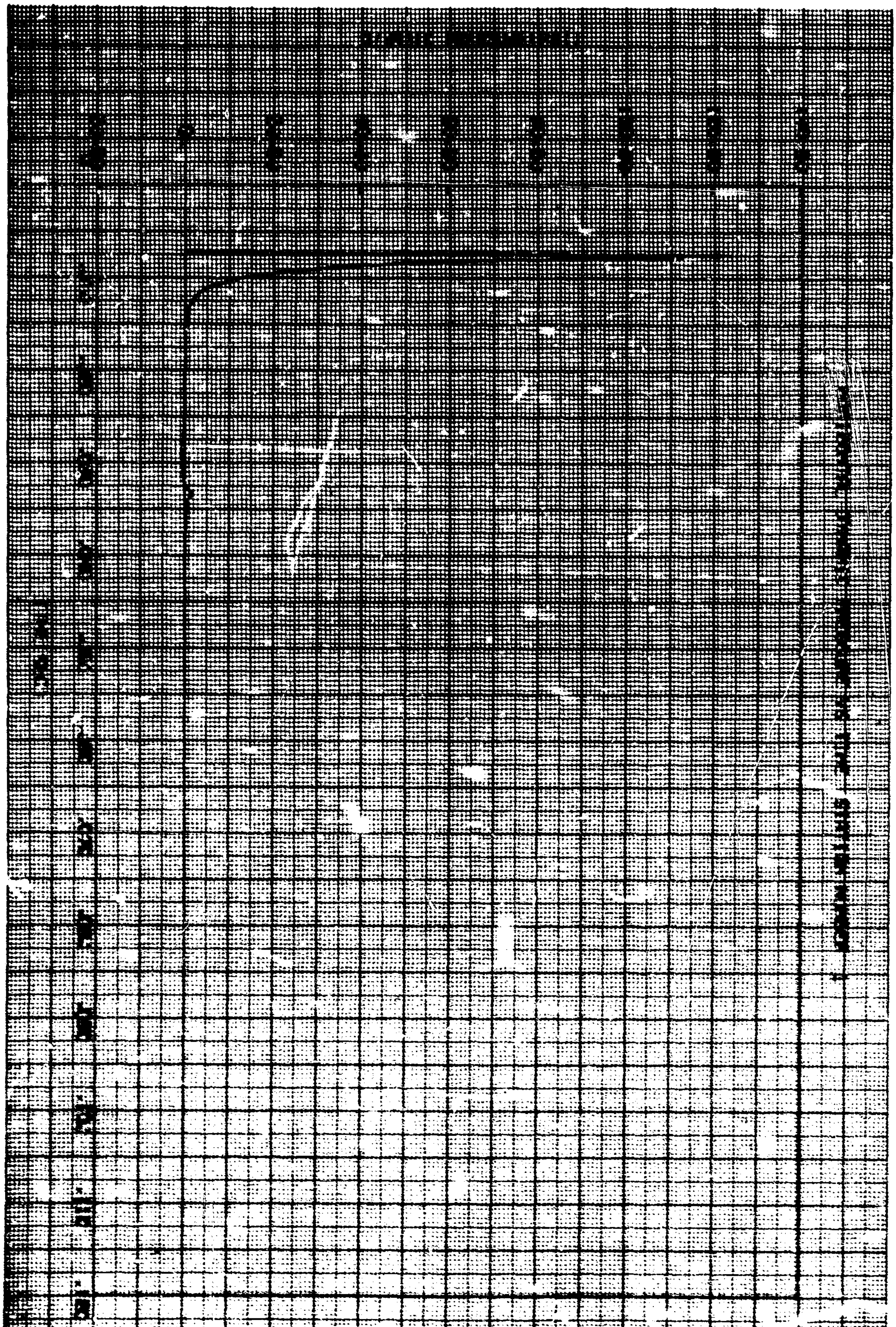


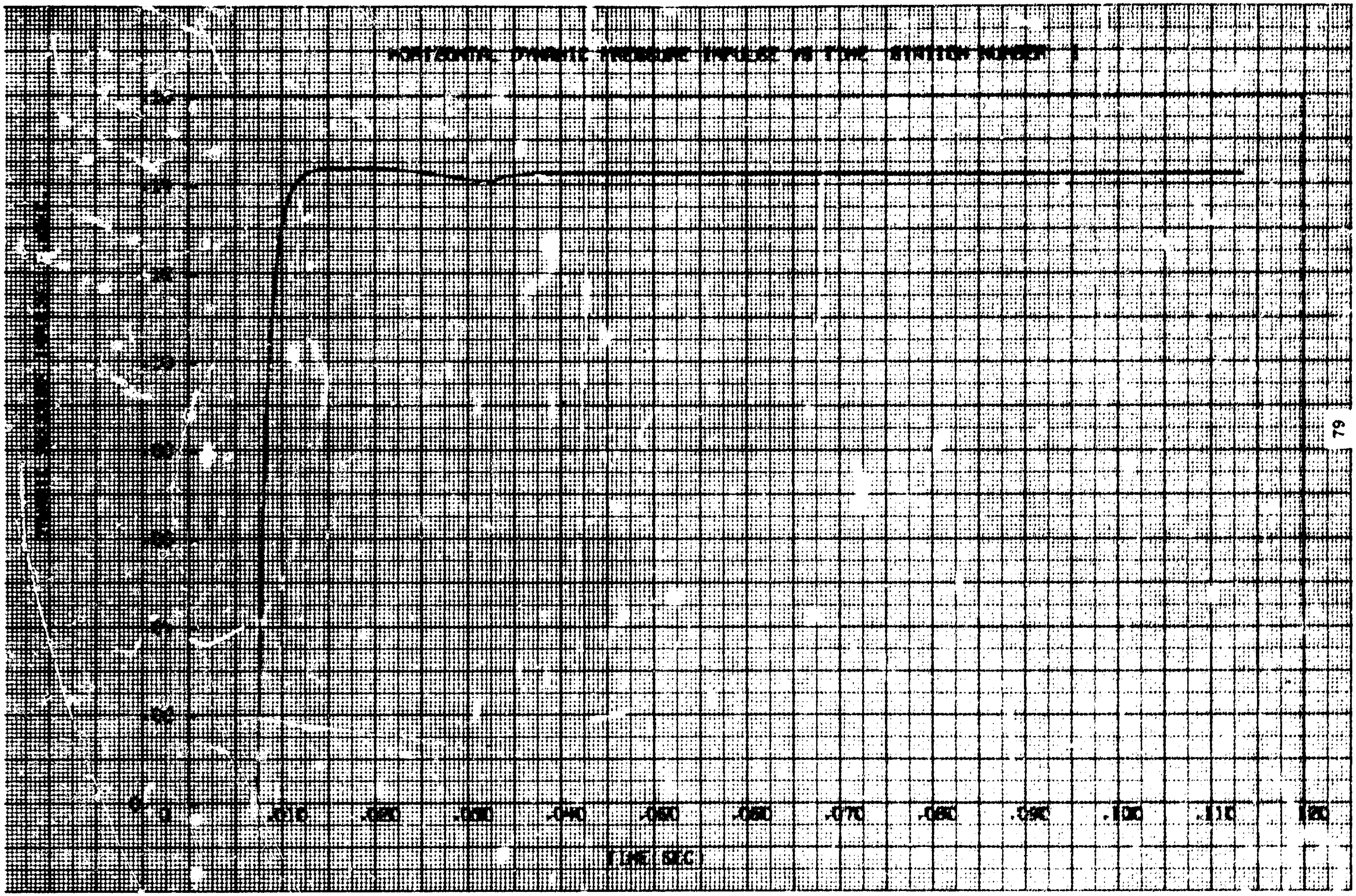


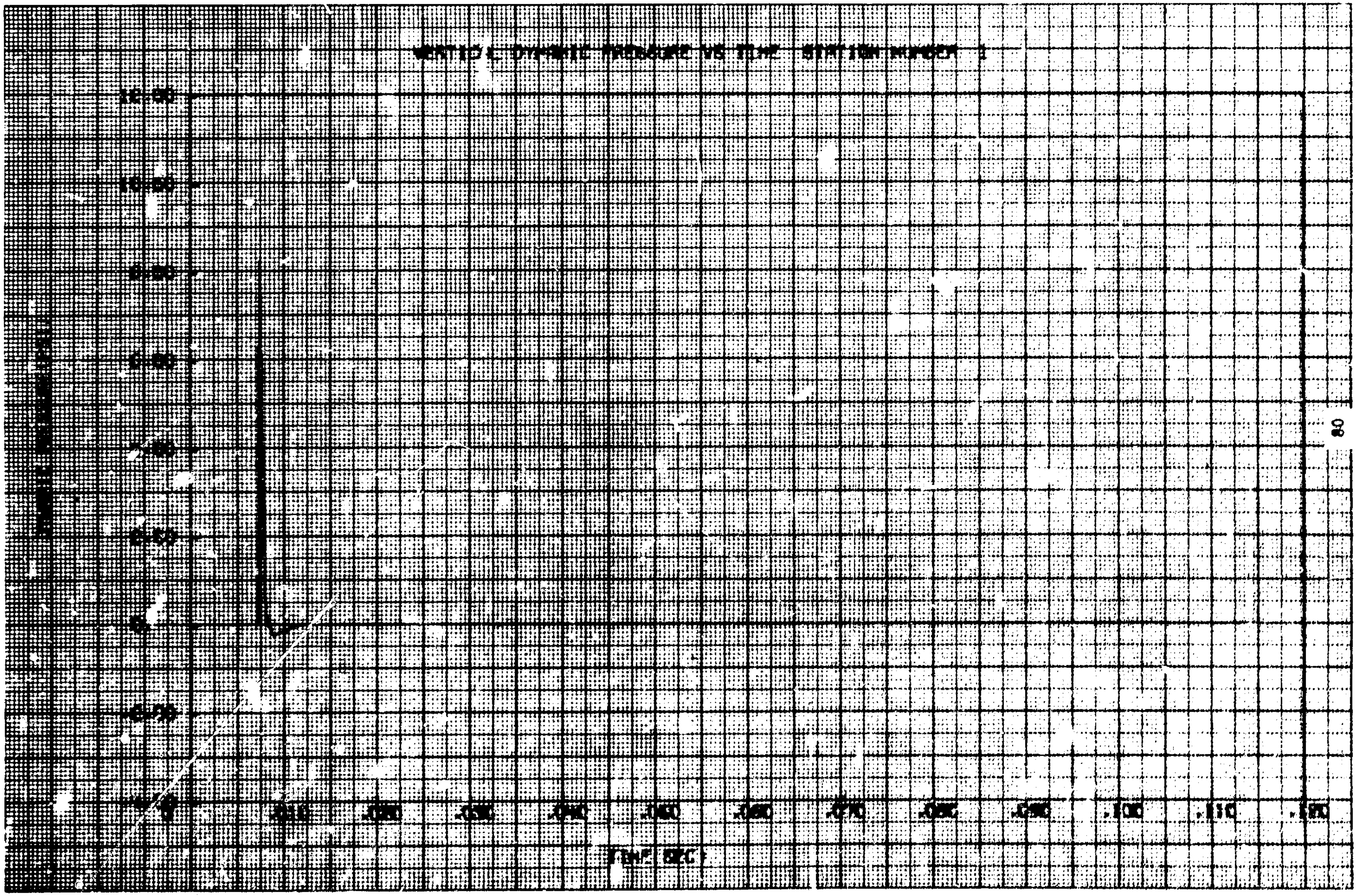
OVER PRESSURE IMPULSE VS TIME STATION NUMBER 1
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

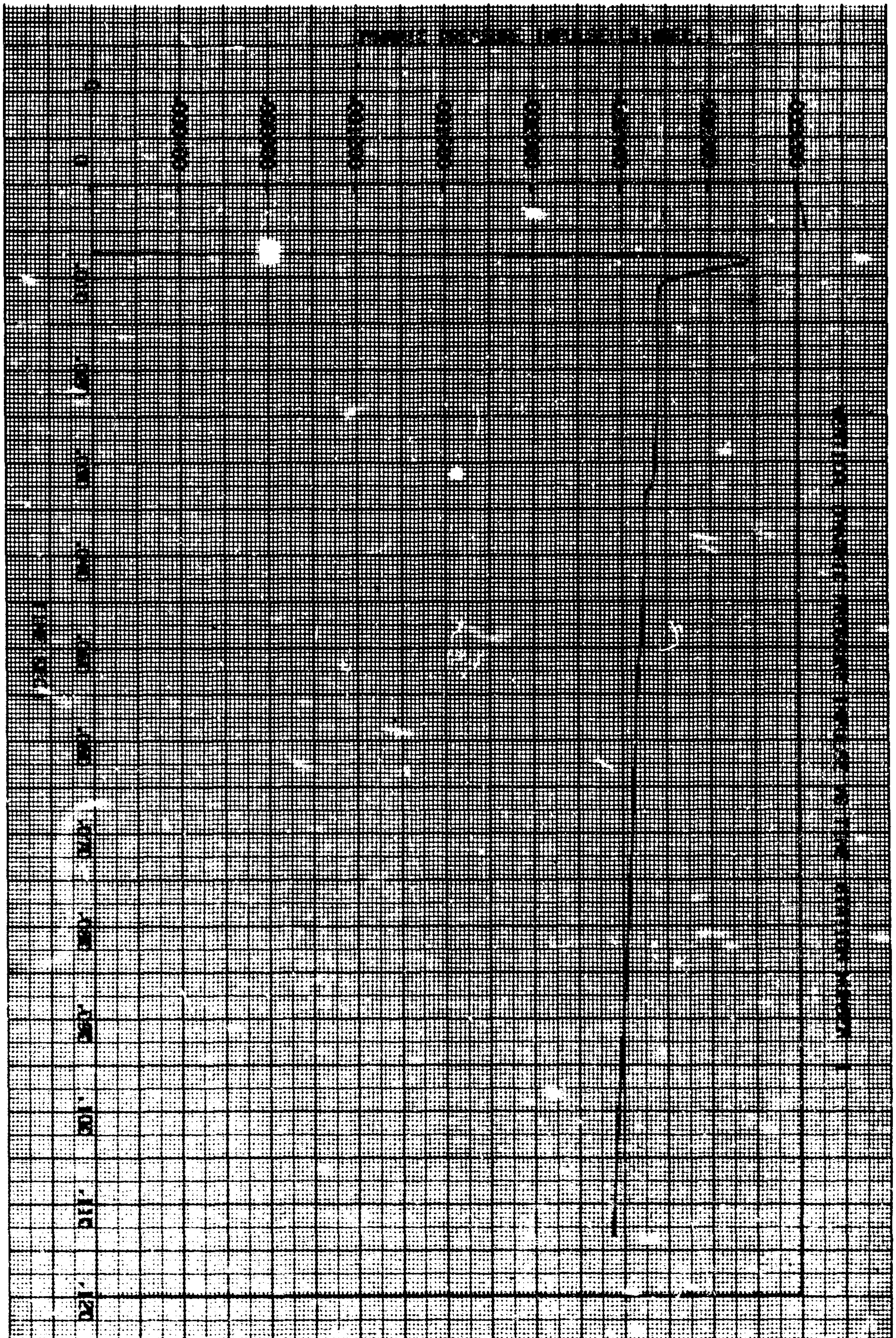

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 1
2800.00
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0
.010
.020
.030
.040
.050
.080
.090
.100
.110
.120
TIME SEC

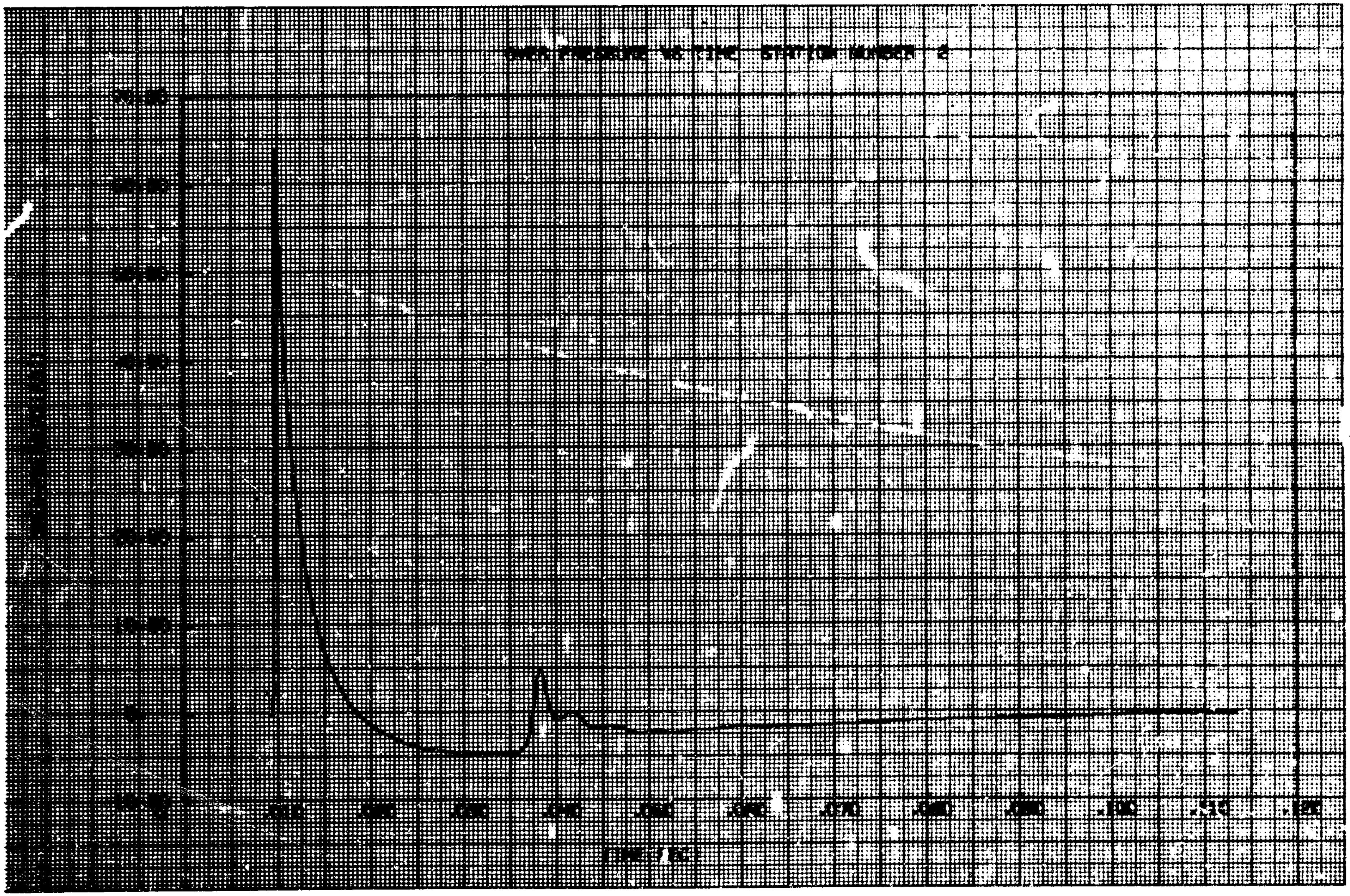


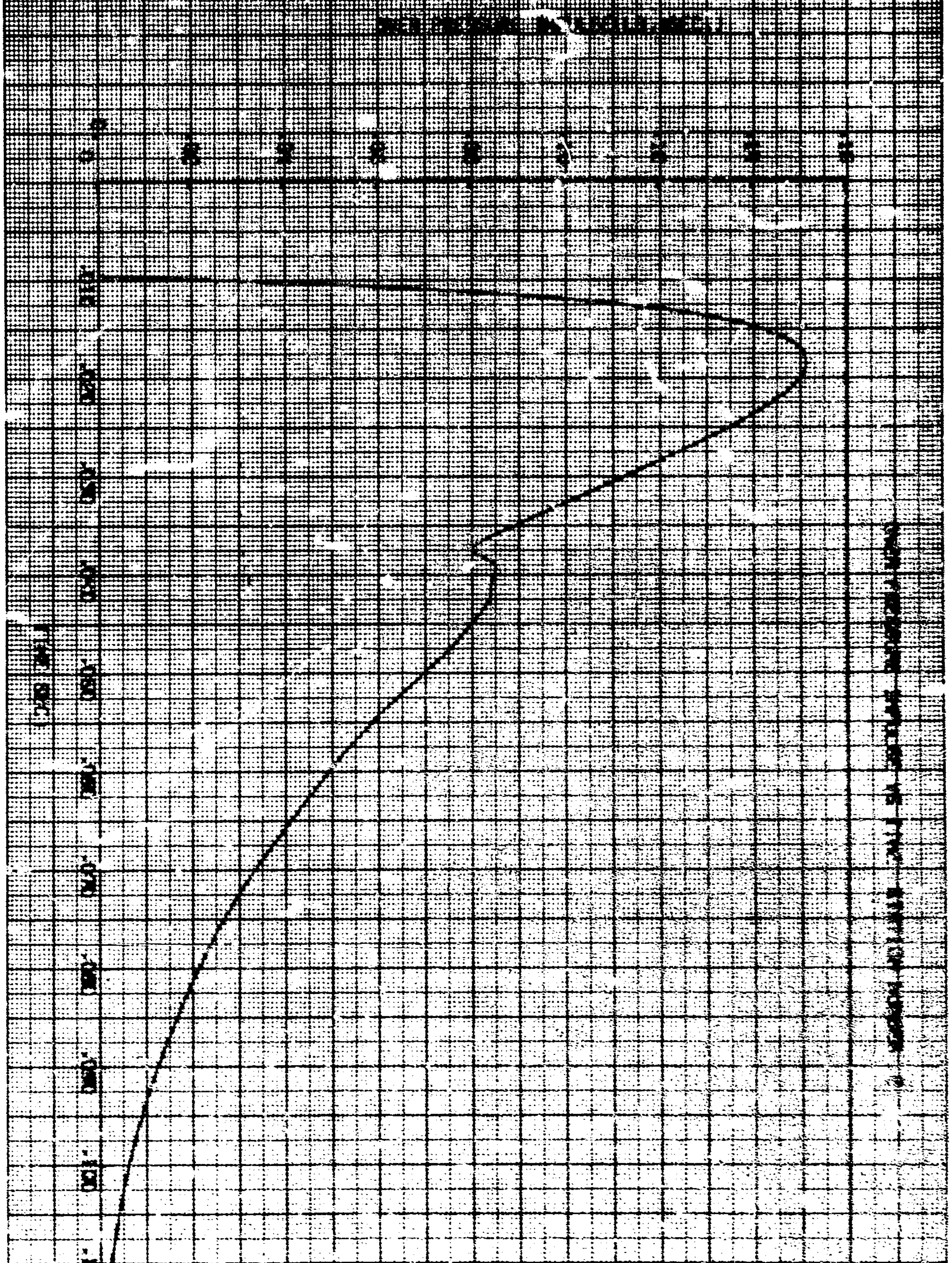


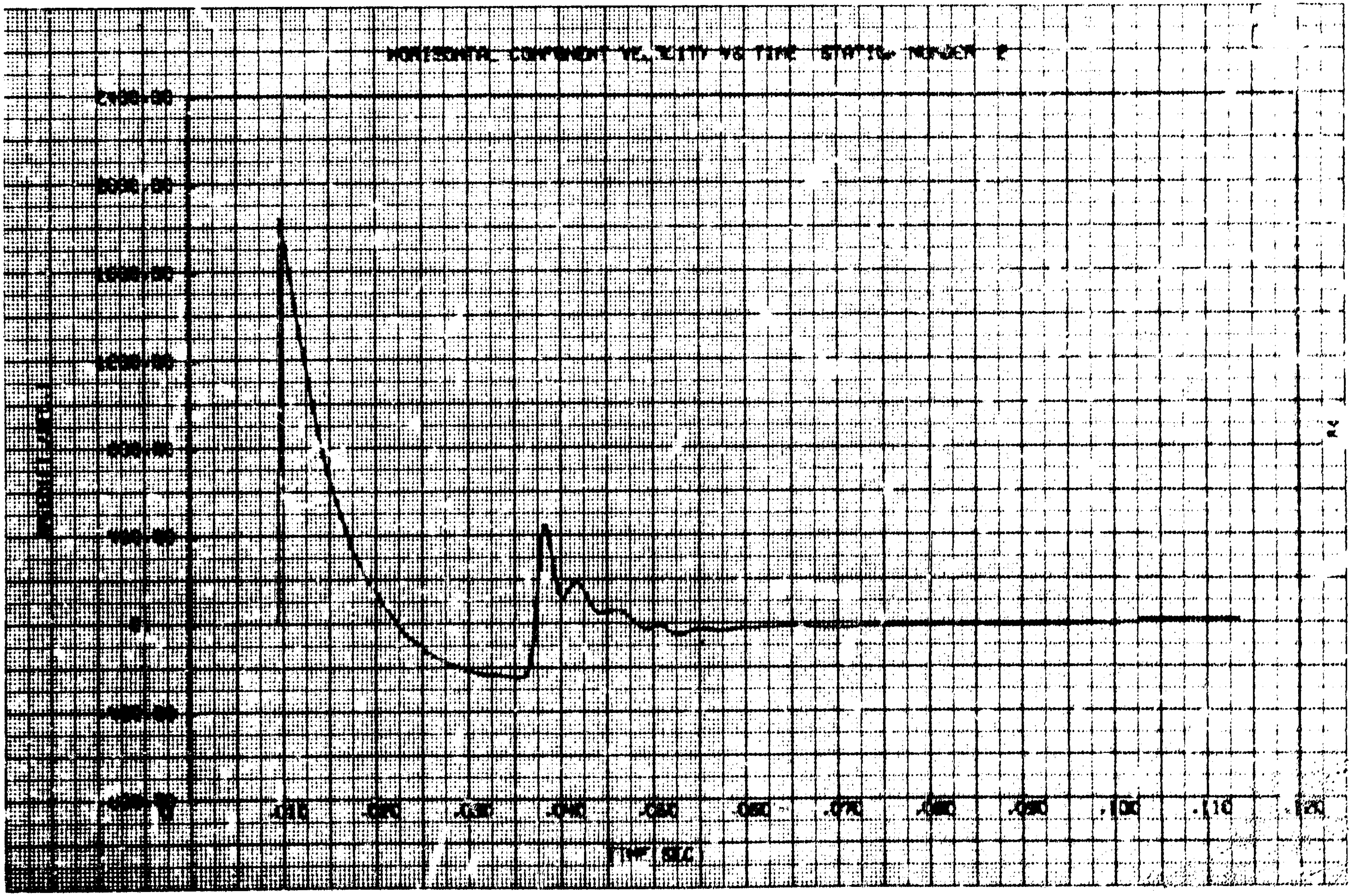

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 1
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

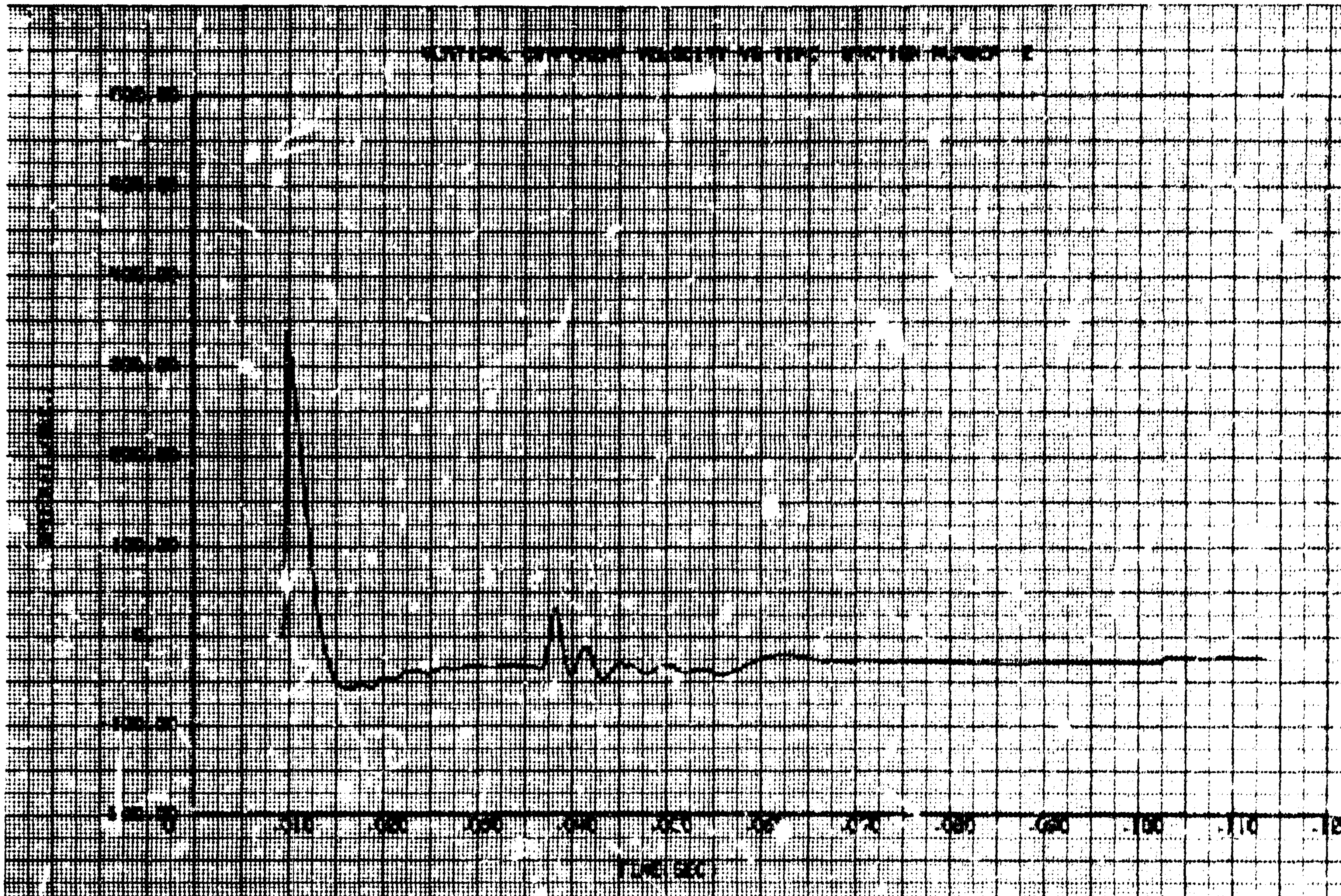

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 1
DYNAMIC PRESSURE(PSI)
TIME (SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

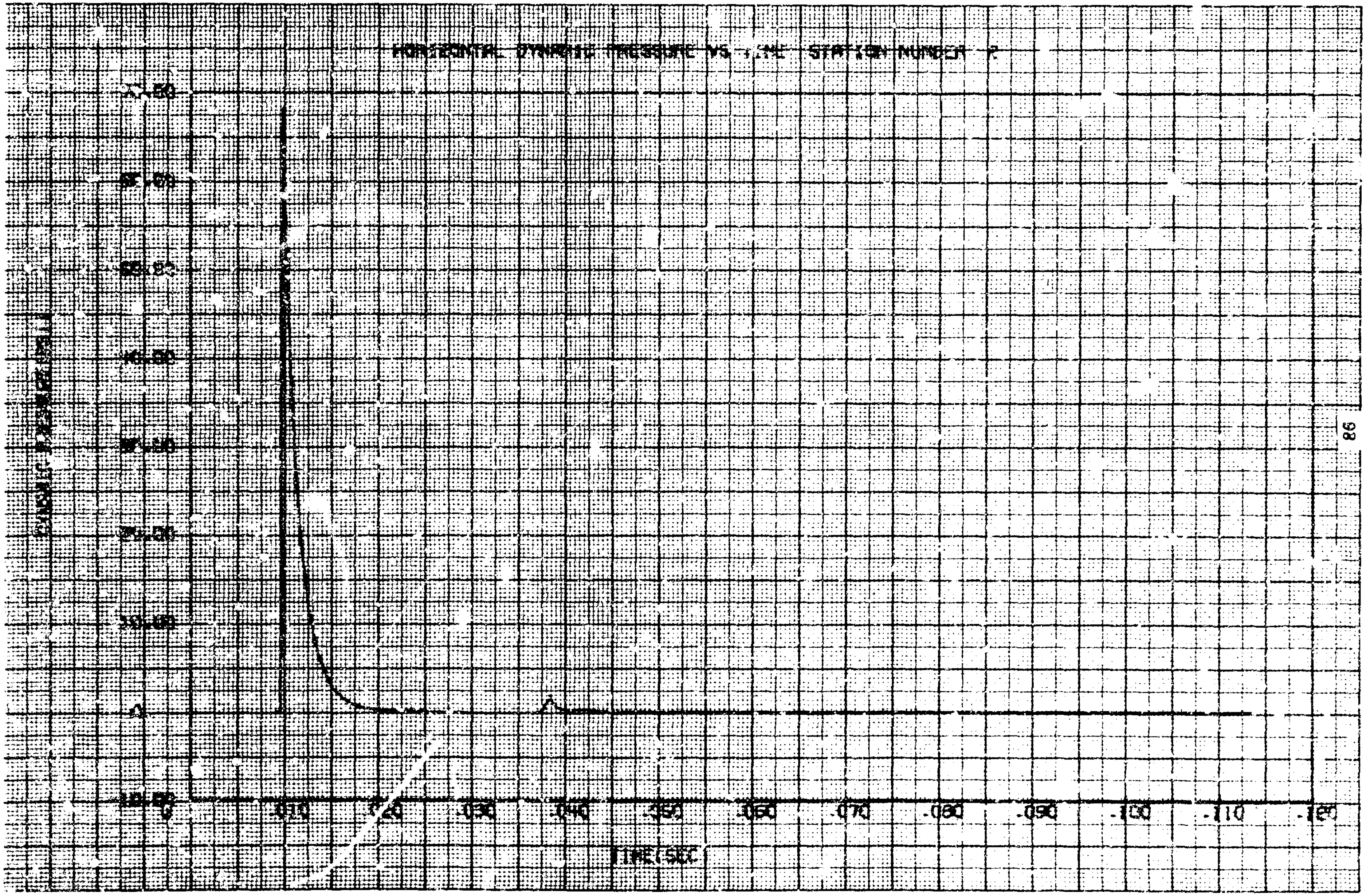

0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

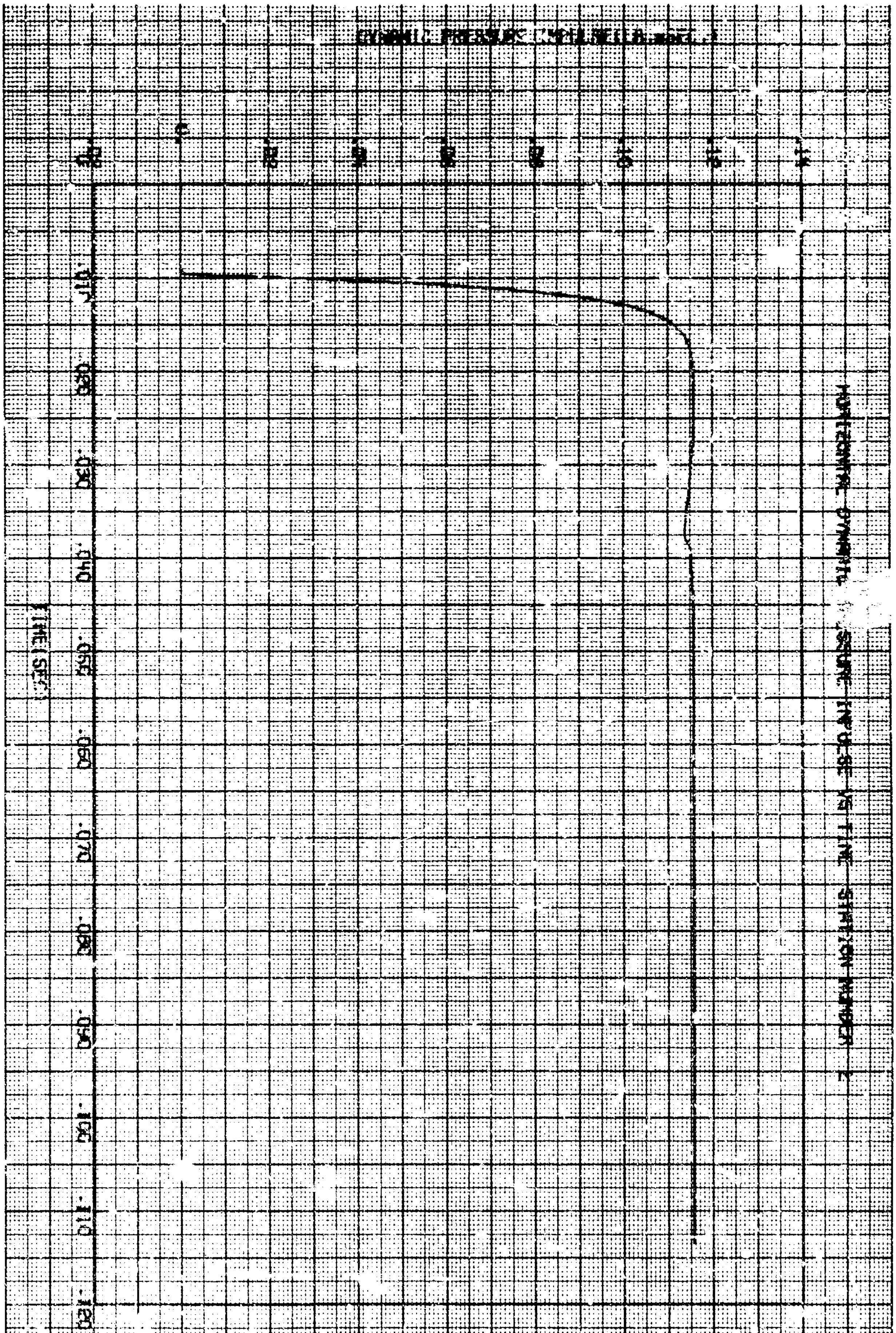



TIME (SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

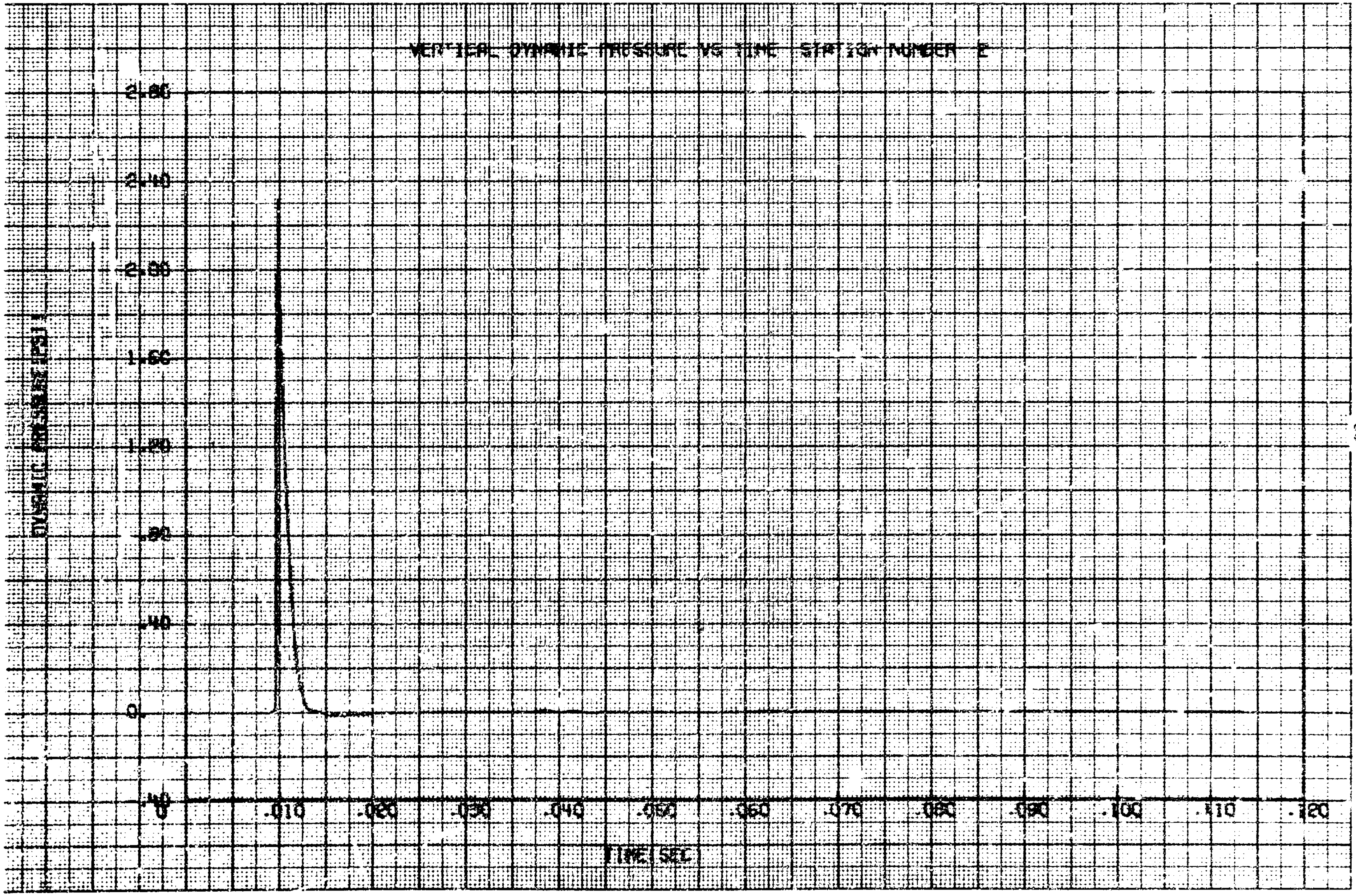

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 2
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0
-400.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

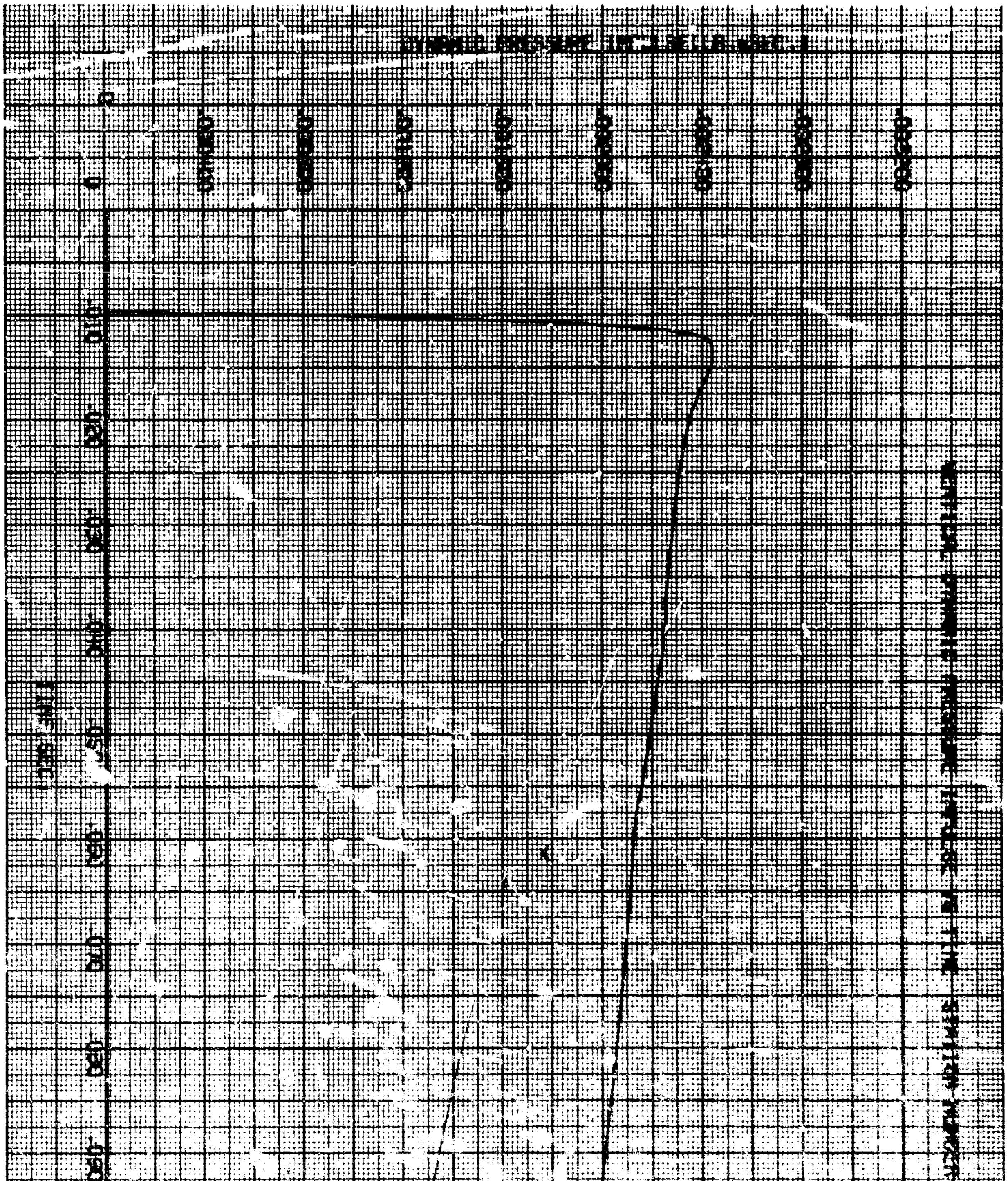

TIME(SEC)

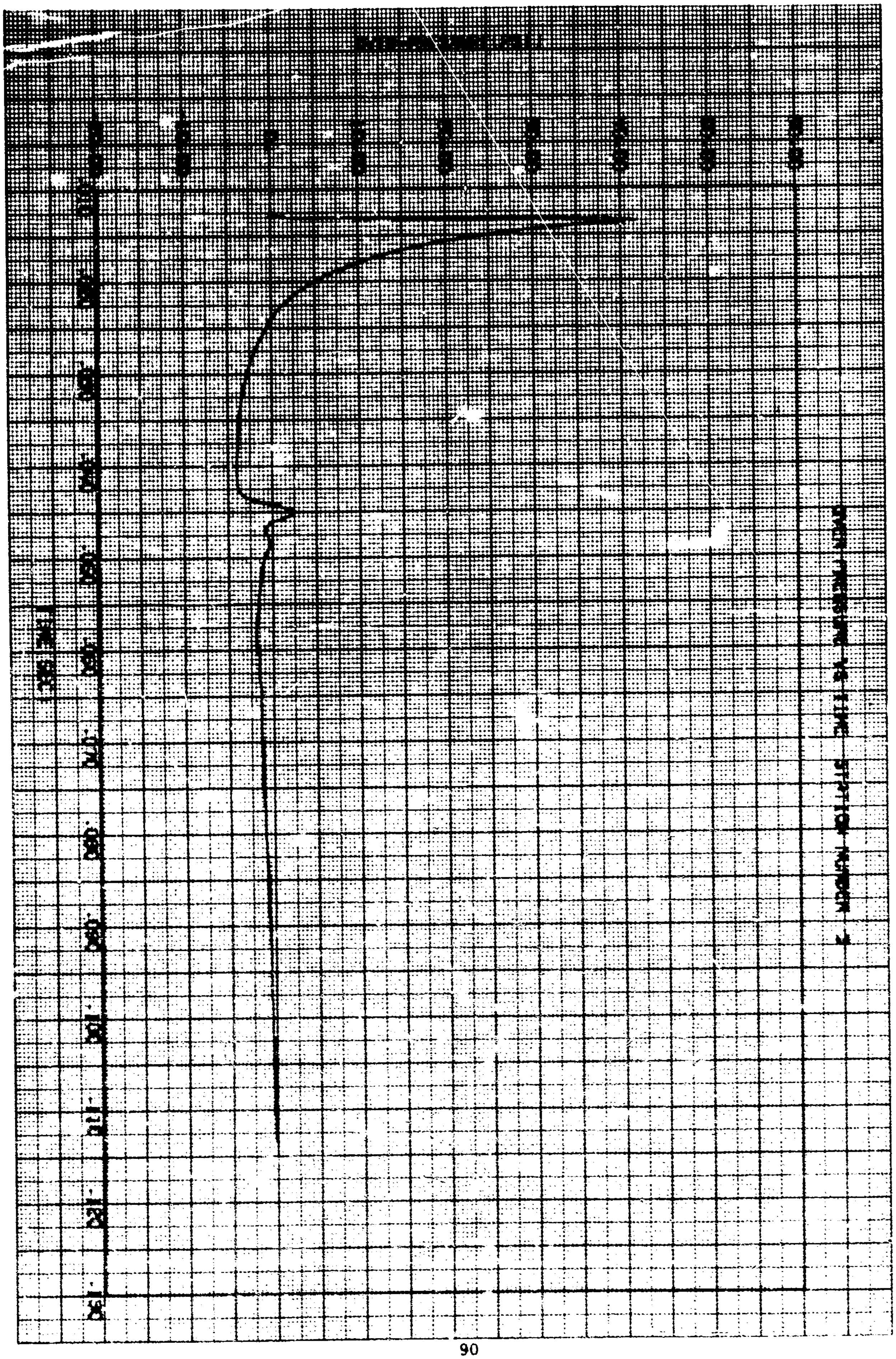

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER
.010
.030
.040
.060
.070
.080
.090
.100
.110
TIME(SEC)

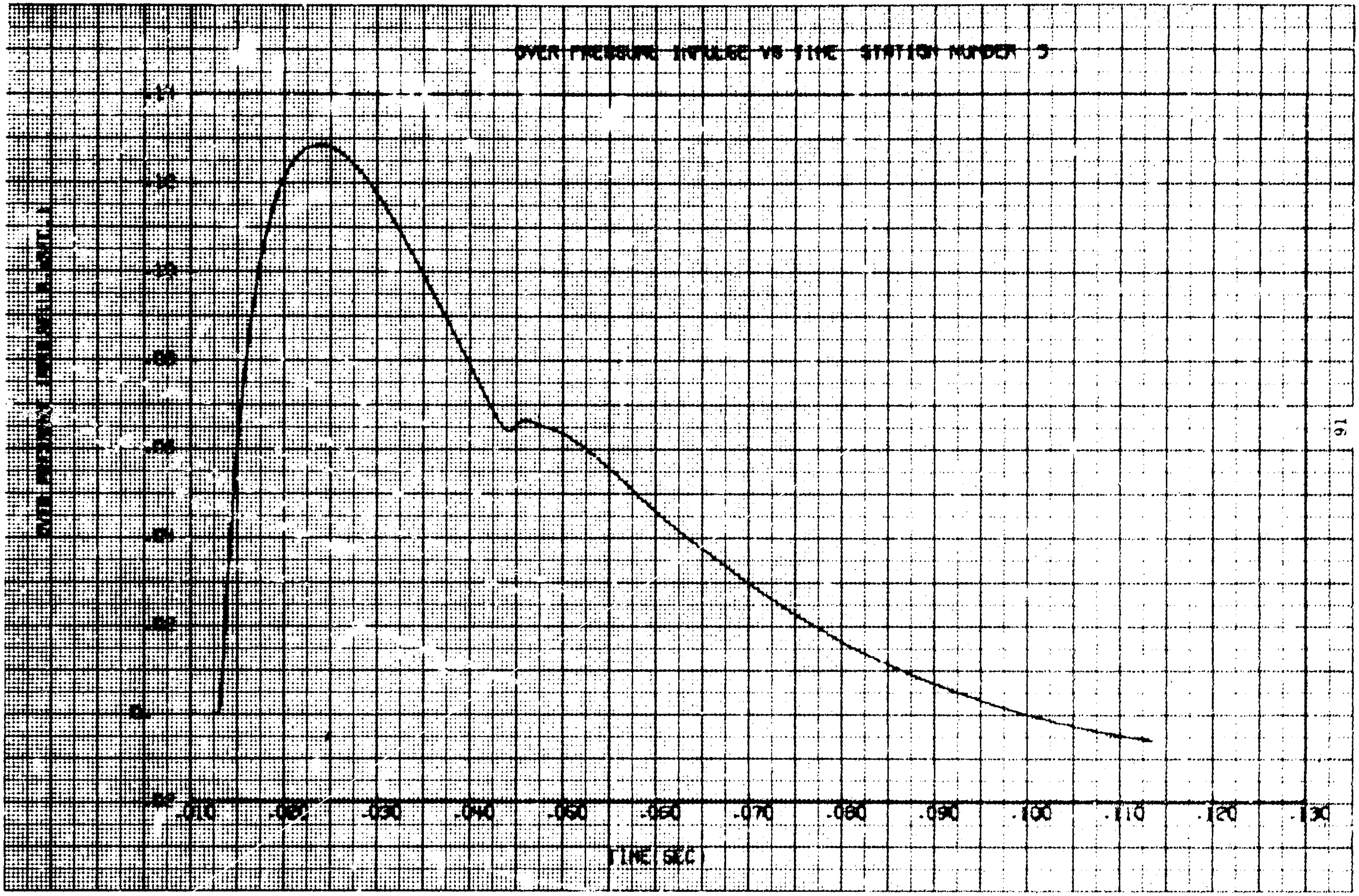


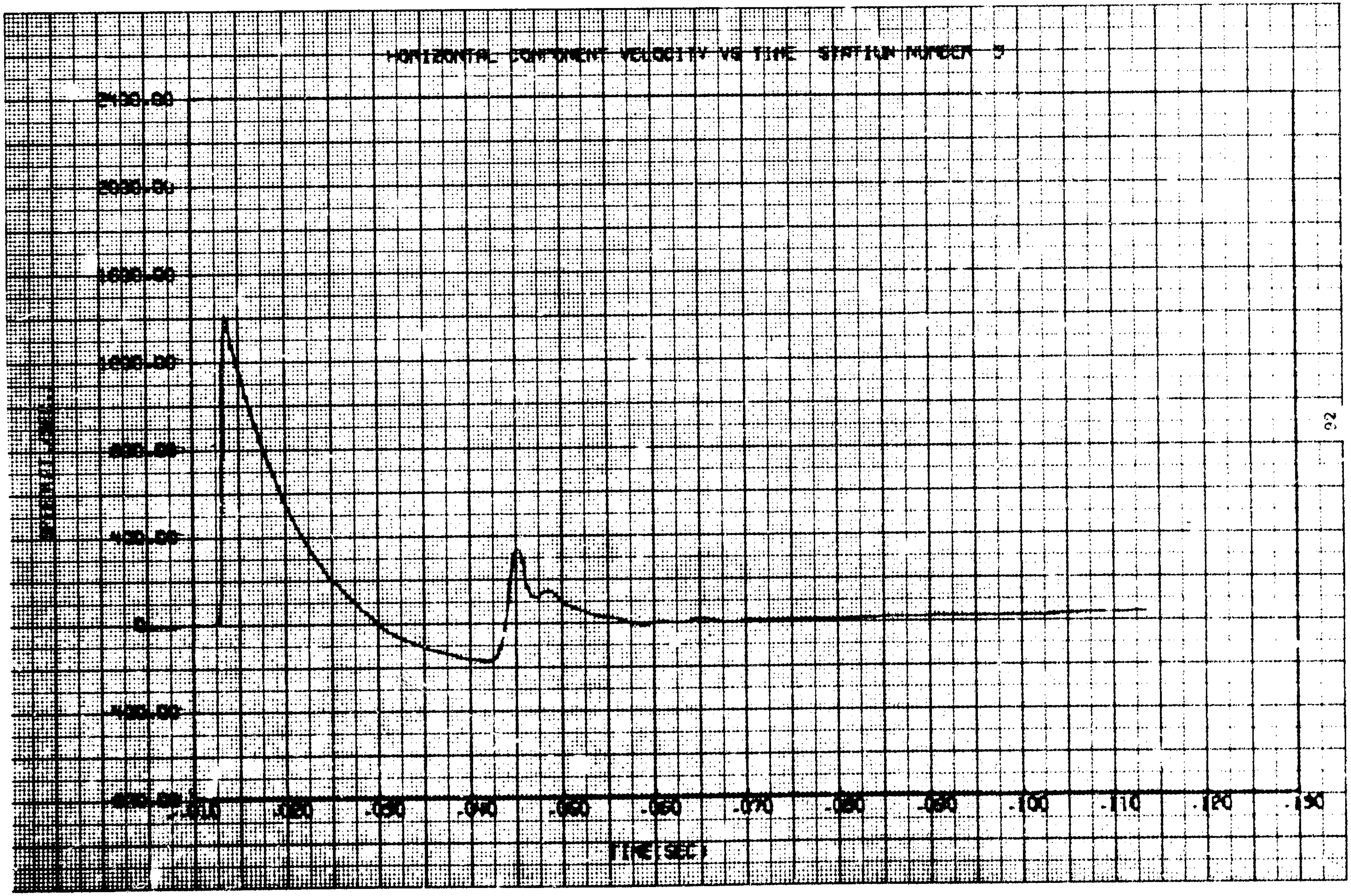
TIME(SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

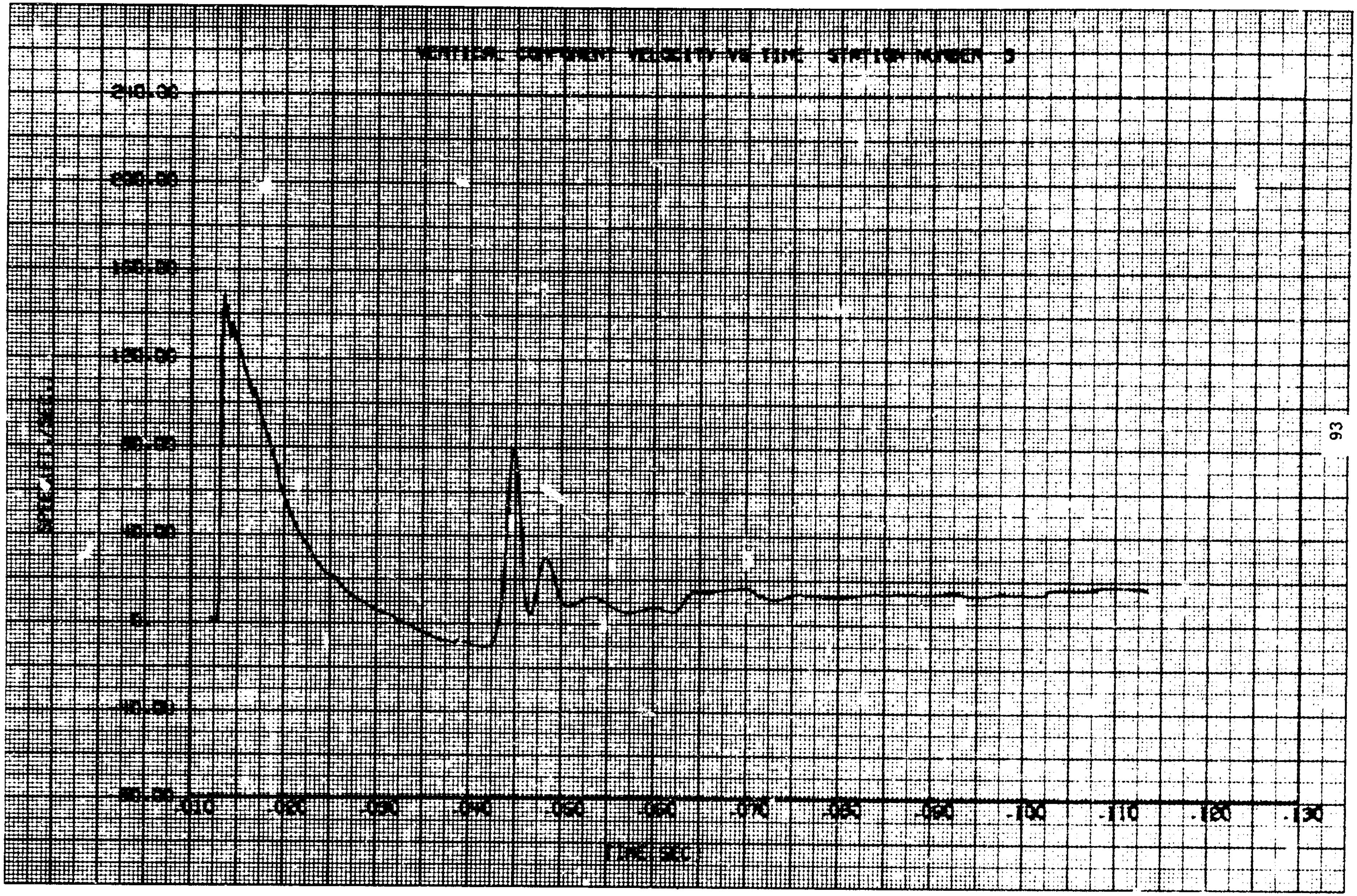

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 2
DYNAMIC PRESSURE(PSI)
2.80
2.40
2.00
1.60
1.20
.80
.40
0.
-.40
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

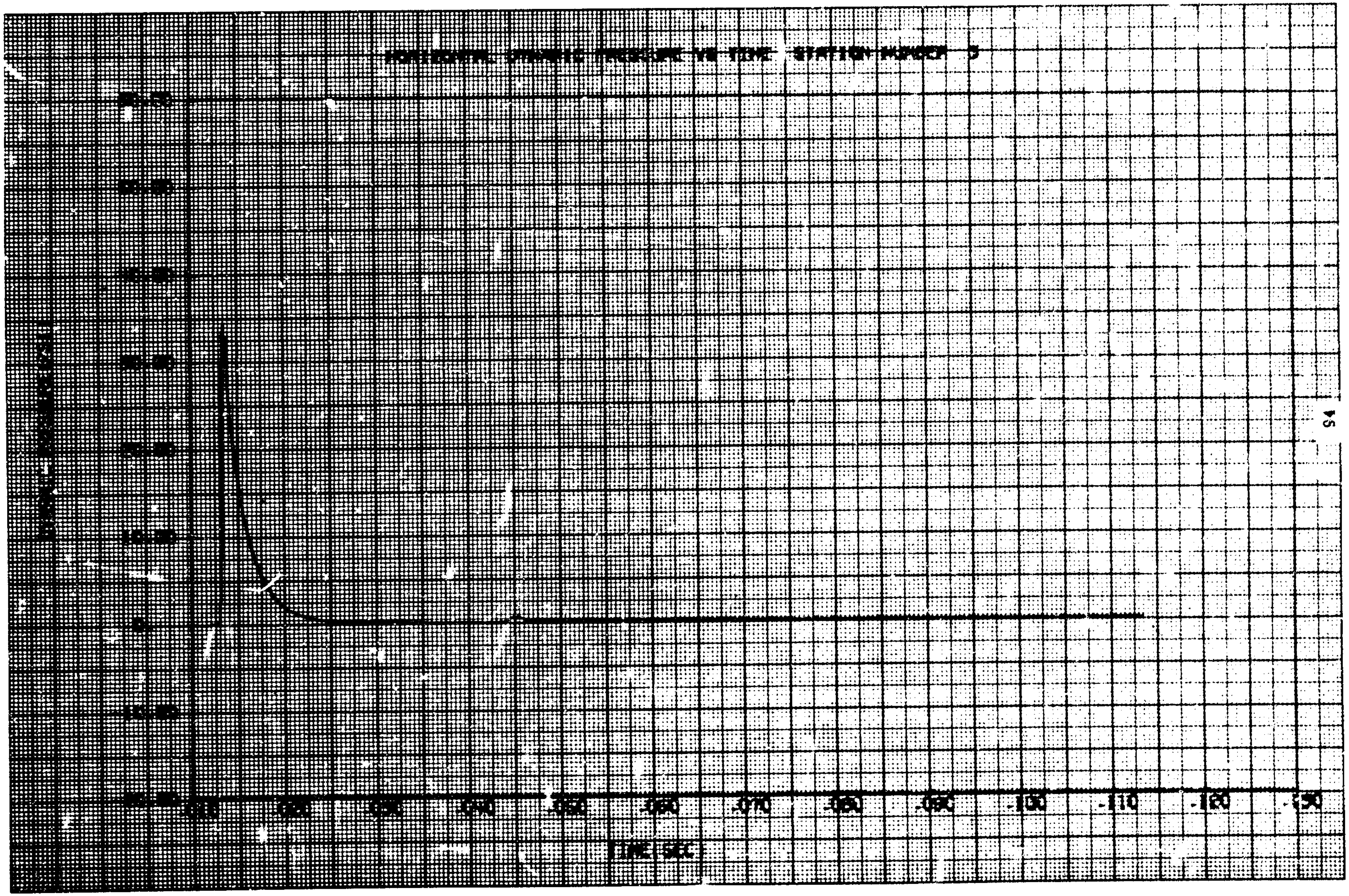

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 2
TIME, SEC
0
.010
.020
.030
.040
.060
.070
.080
.090
.100
.110
.120

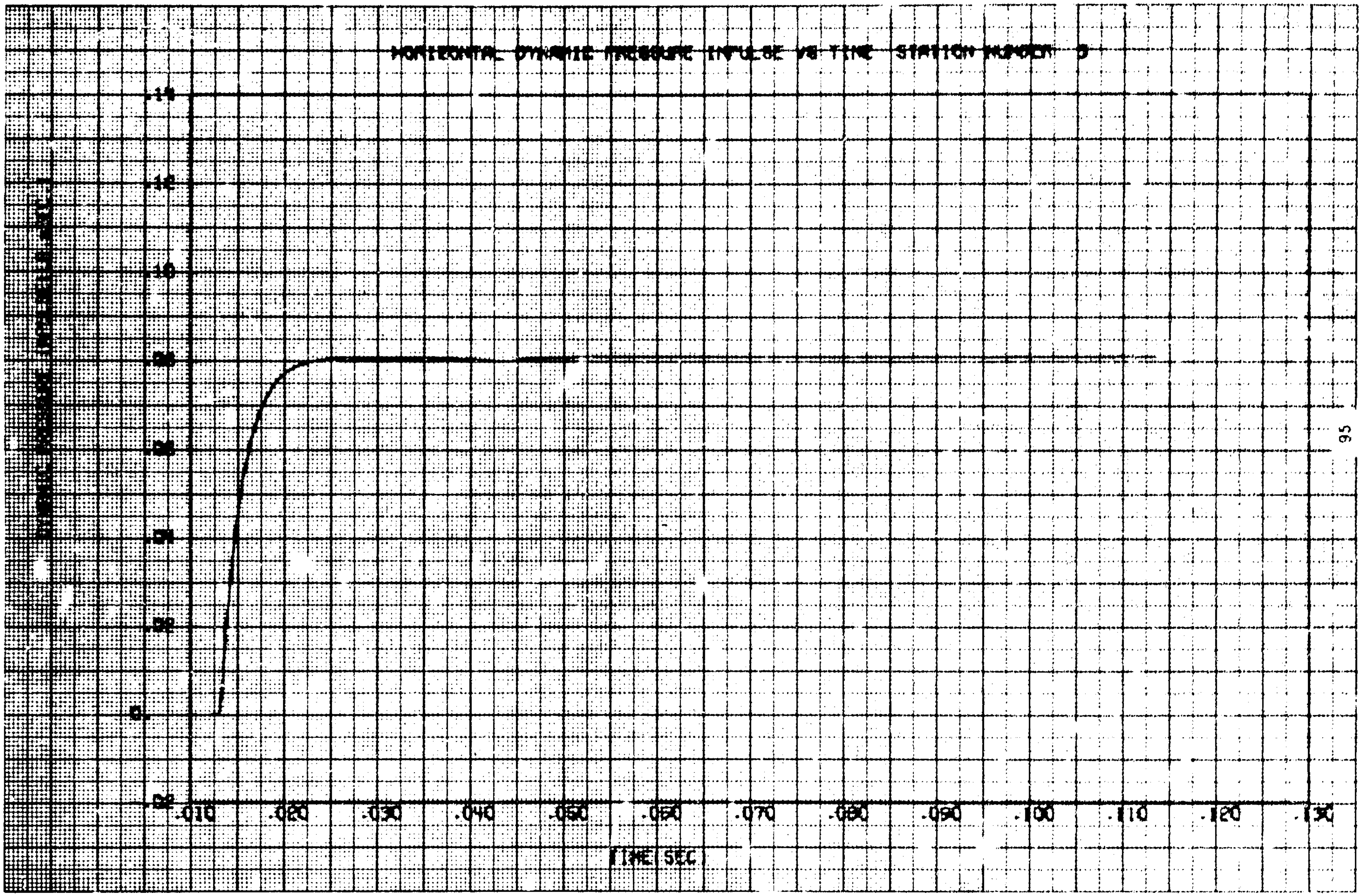

OVER PRESSURE VS TIME STATION NUMBER 2
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC


OVER-PRESSURE IMPULSE VS TIME STATION NUMBER 3
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

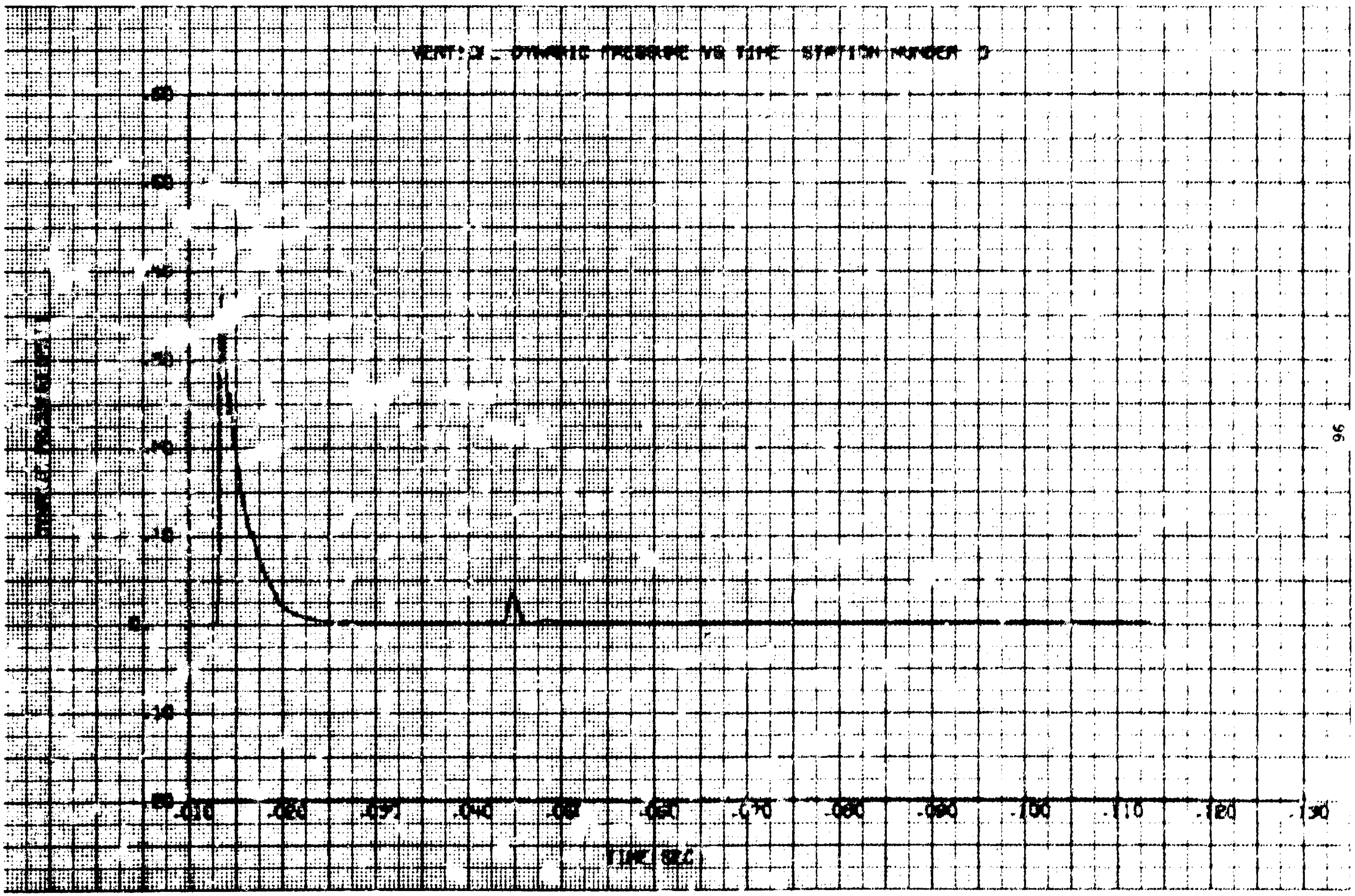

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 3
2400.00
2000.00
0
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

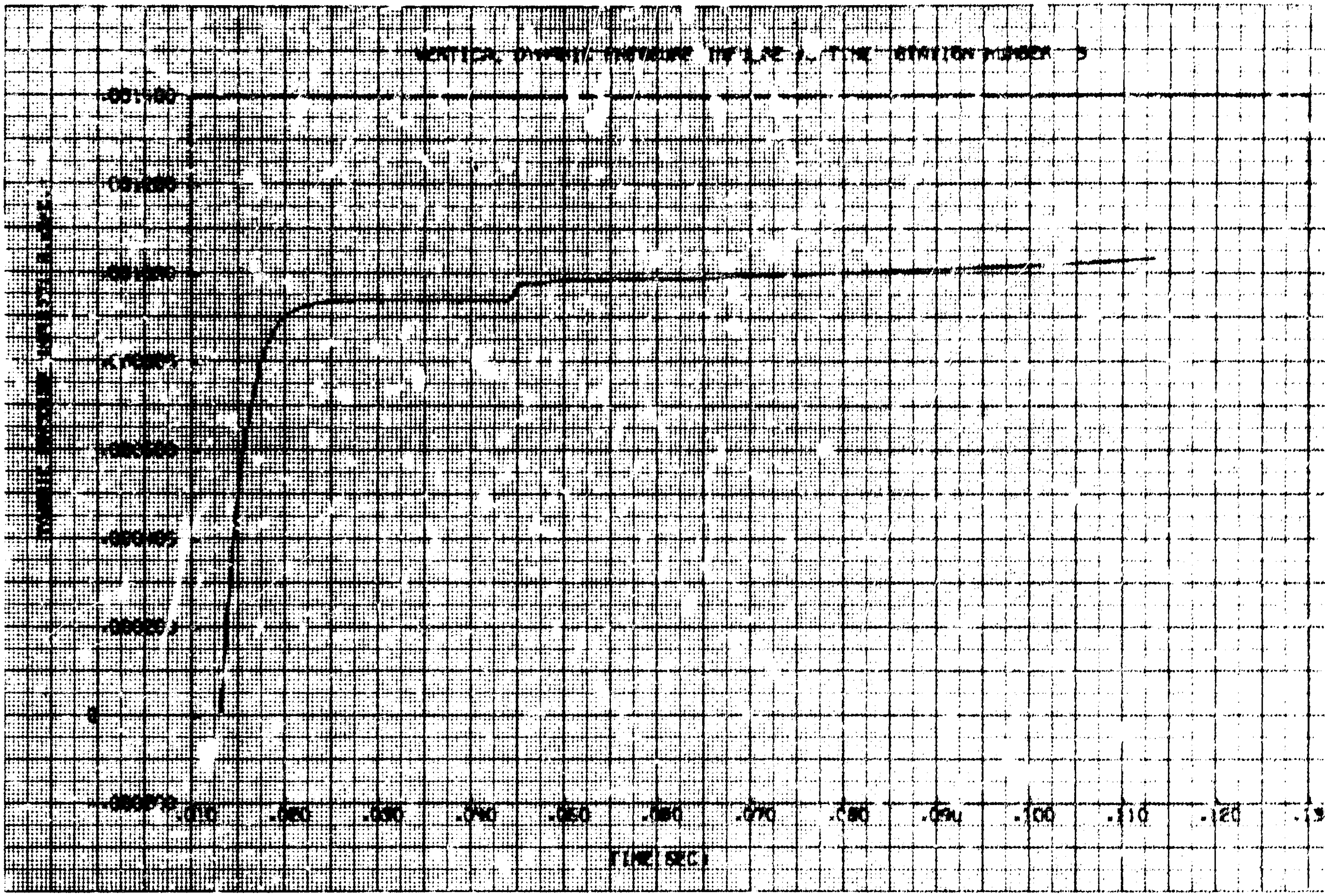

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER
SPEED (FT./SEC.)
240.00
200.00
160.00
120.00
80.00
40.00
0.
-40.00
-80.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

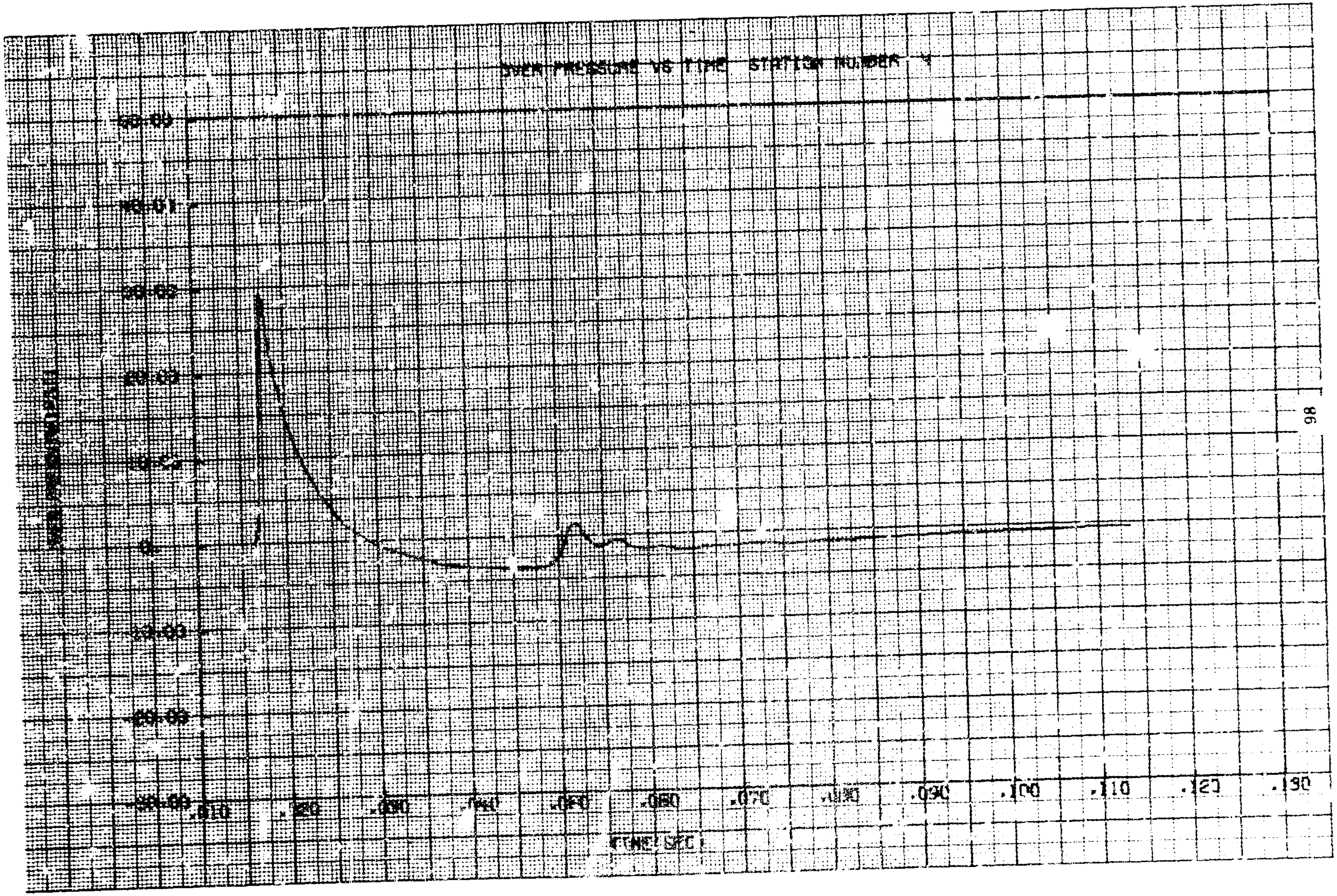

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 3
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

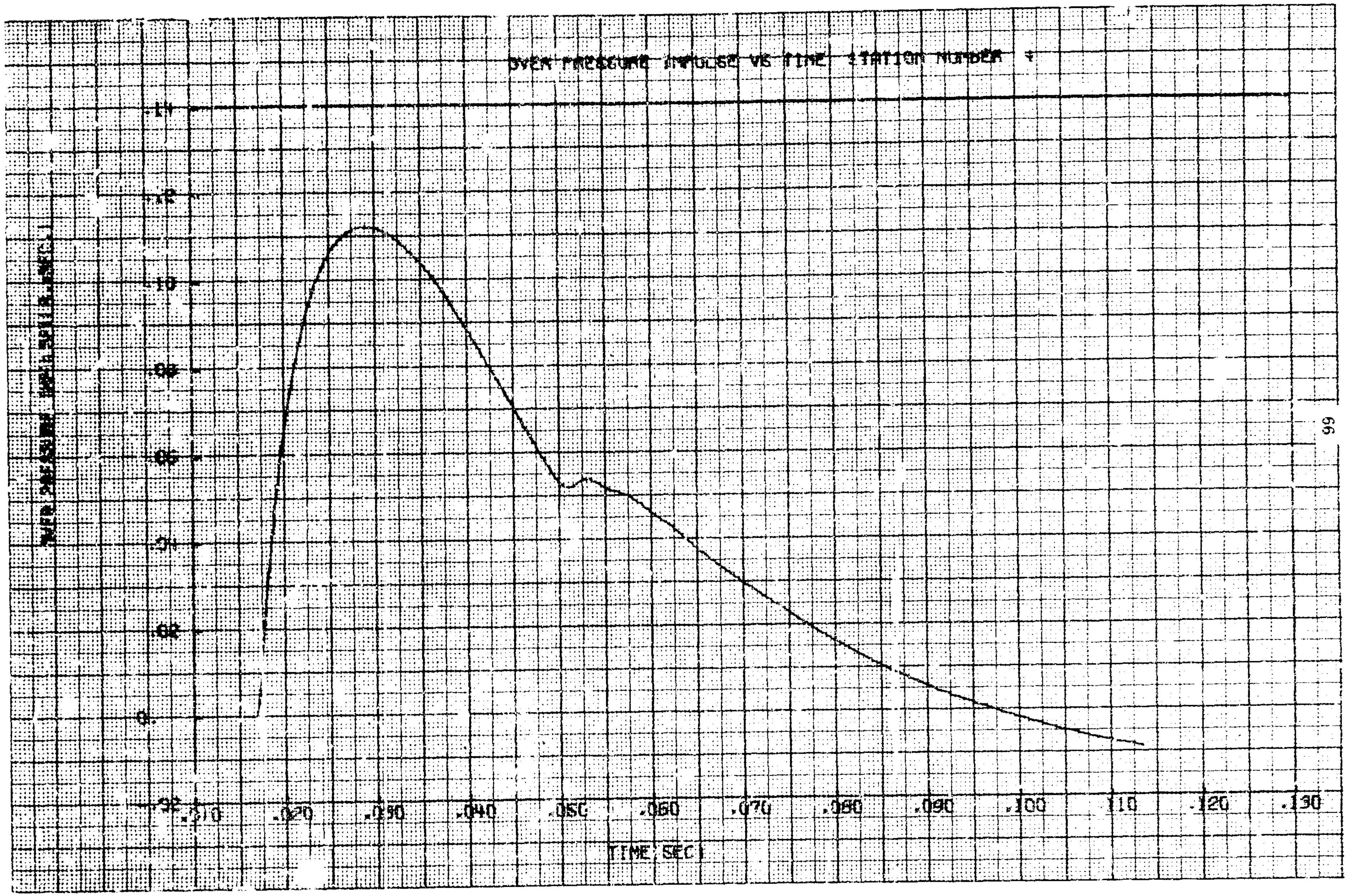


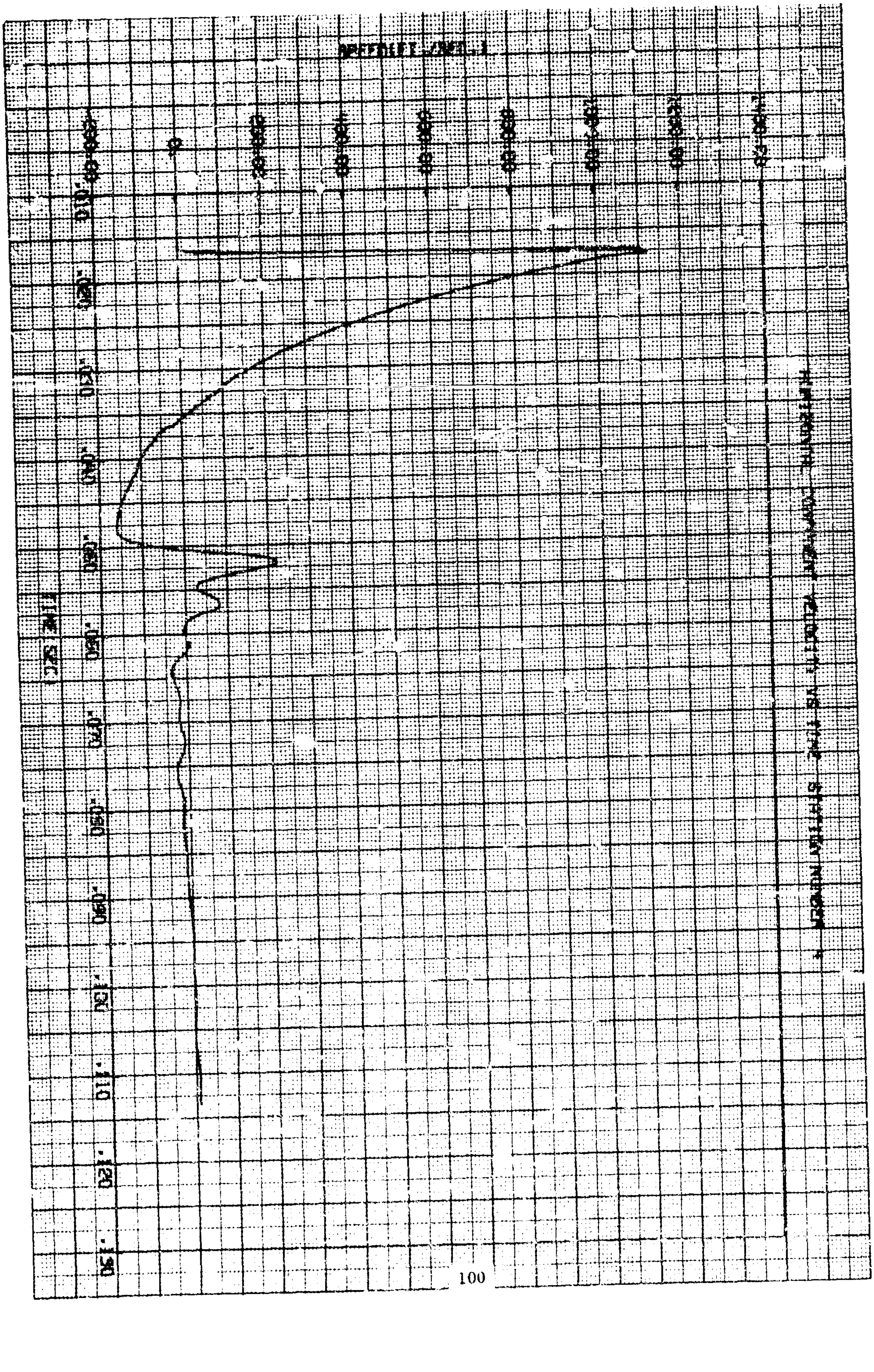
HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER
.14
.12
.10
.08
.06
.04
.02
0.
-.02
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

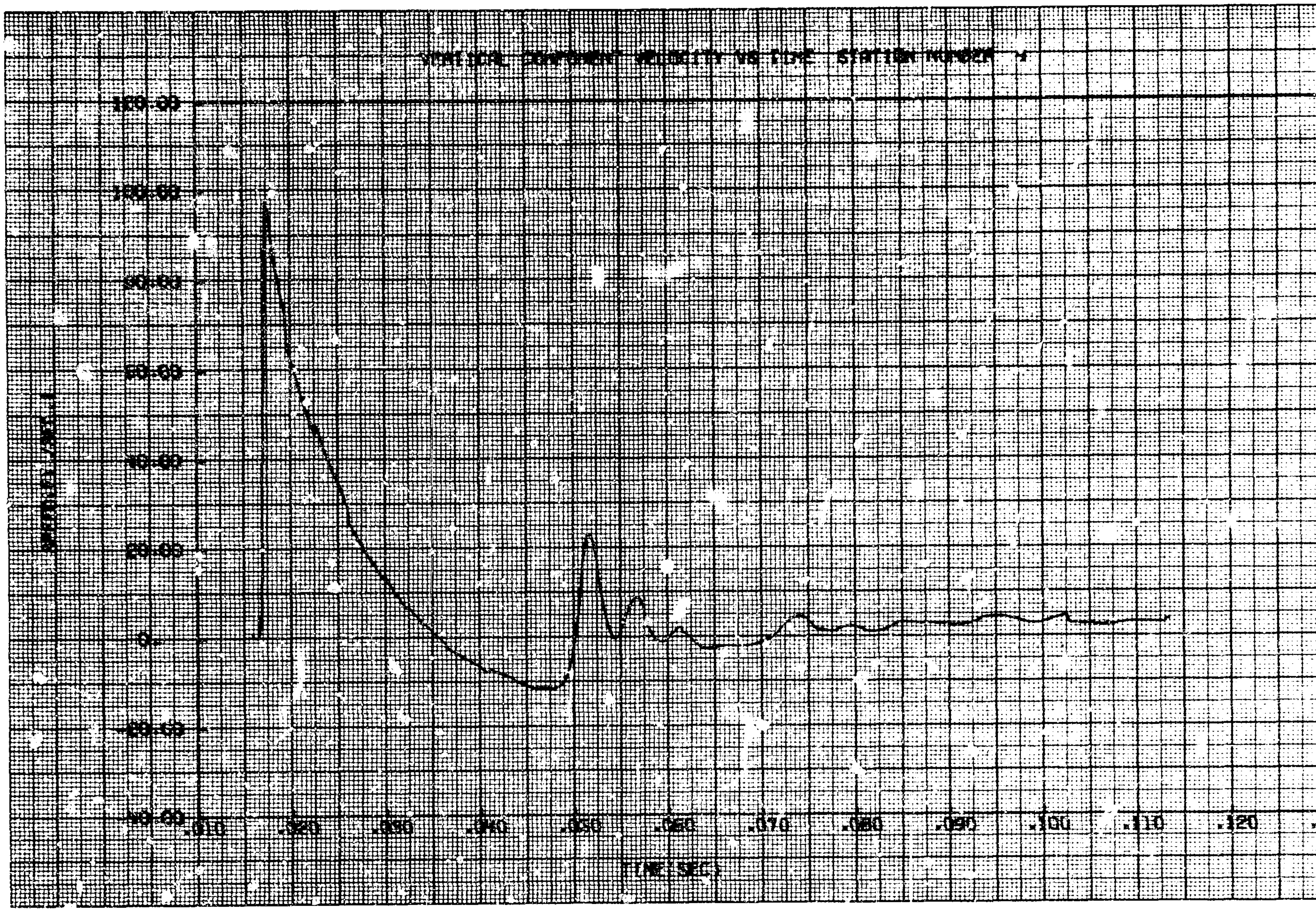

DYNAMIC PRESSURE VS TIME
TIME SEC
.010
.020
.040
.060
.070
.080
.090
.100
.110
.120
.130

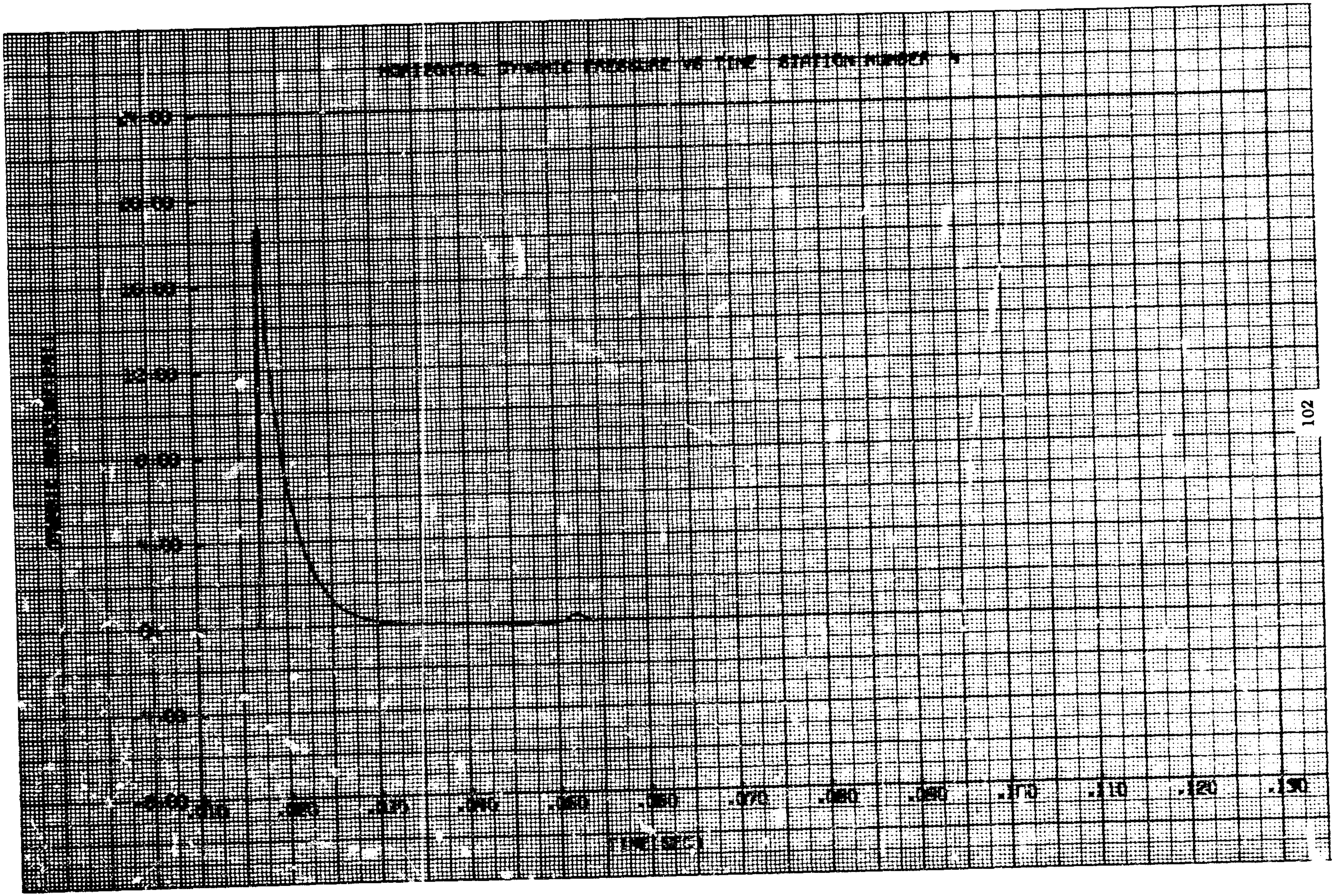

.010
.020
.030
.040
.050
.060
.070
.080
.100
.110
.120
TIME (SEC)


OVER PRESSURE VS TIME STATION NUMBER 4
TIME (SEC)

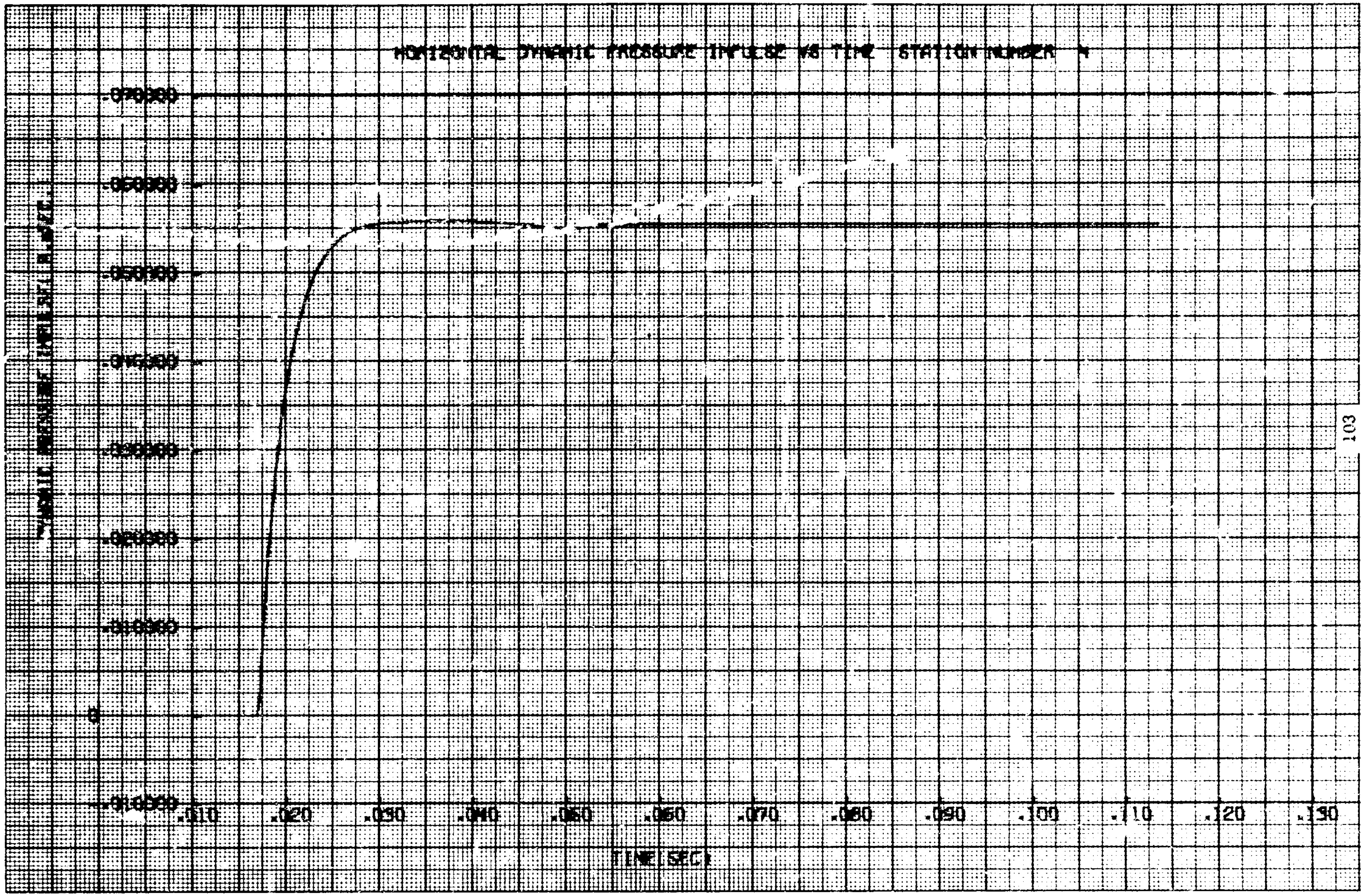

OVER PRESSURE IMPULSE VS TIME STATION NUMBER 4
.14
.12
.10
.08
.06
.04
.02
0
-.02
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC)

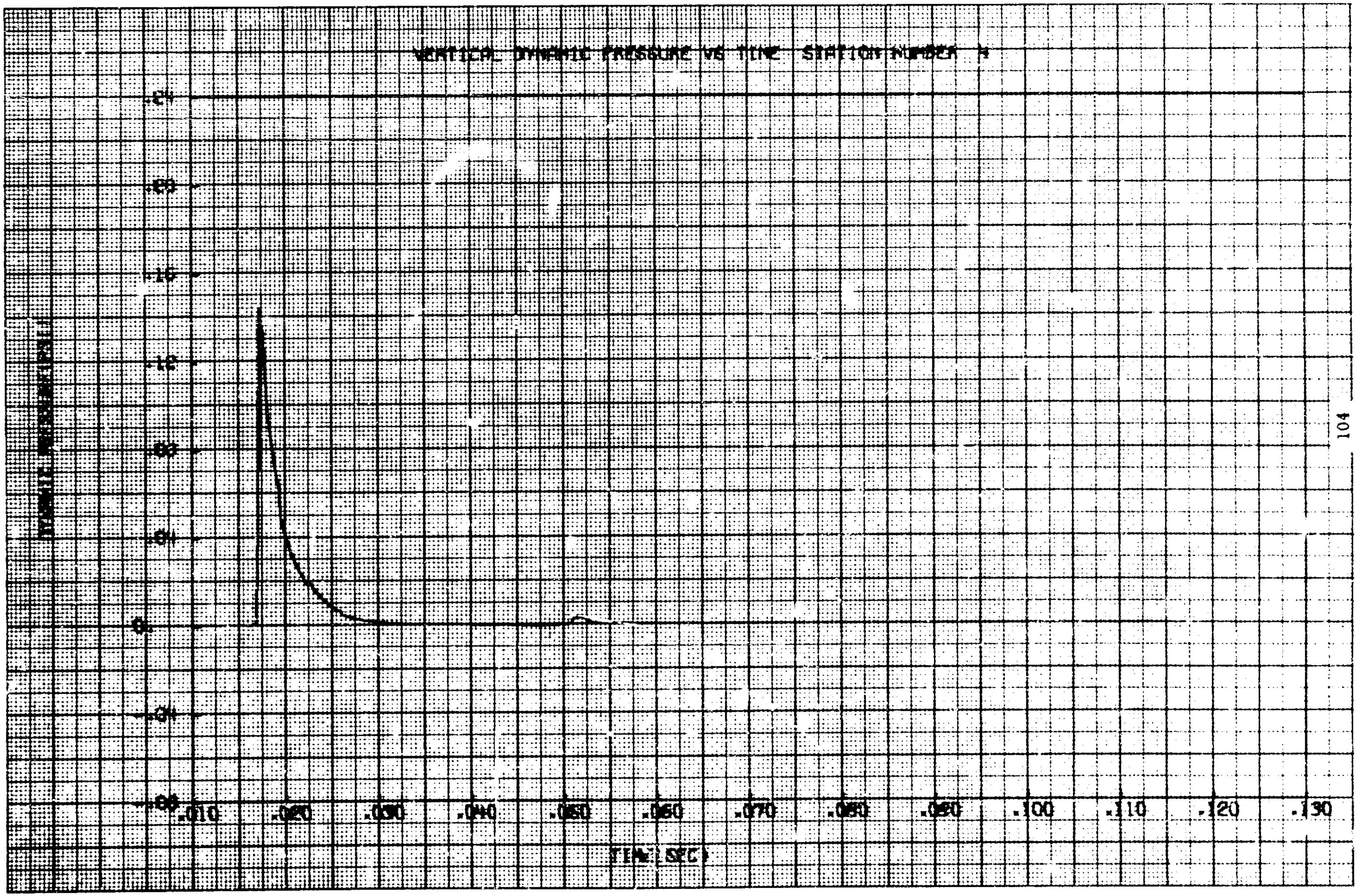

TIME SEC
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130

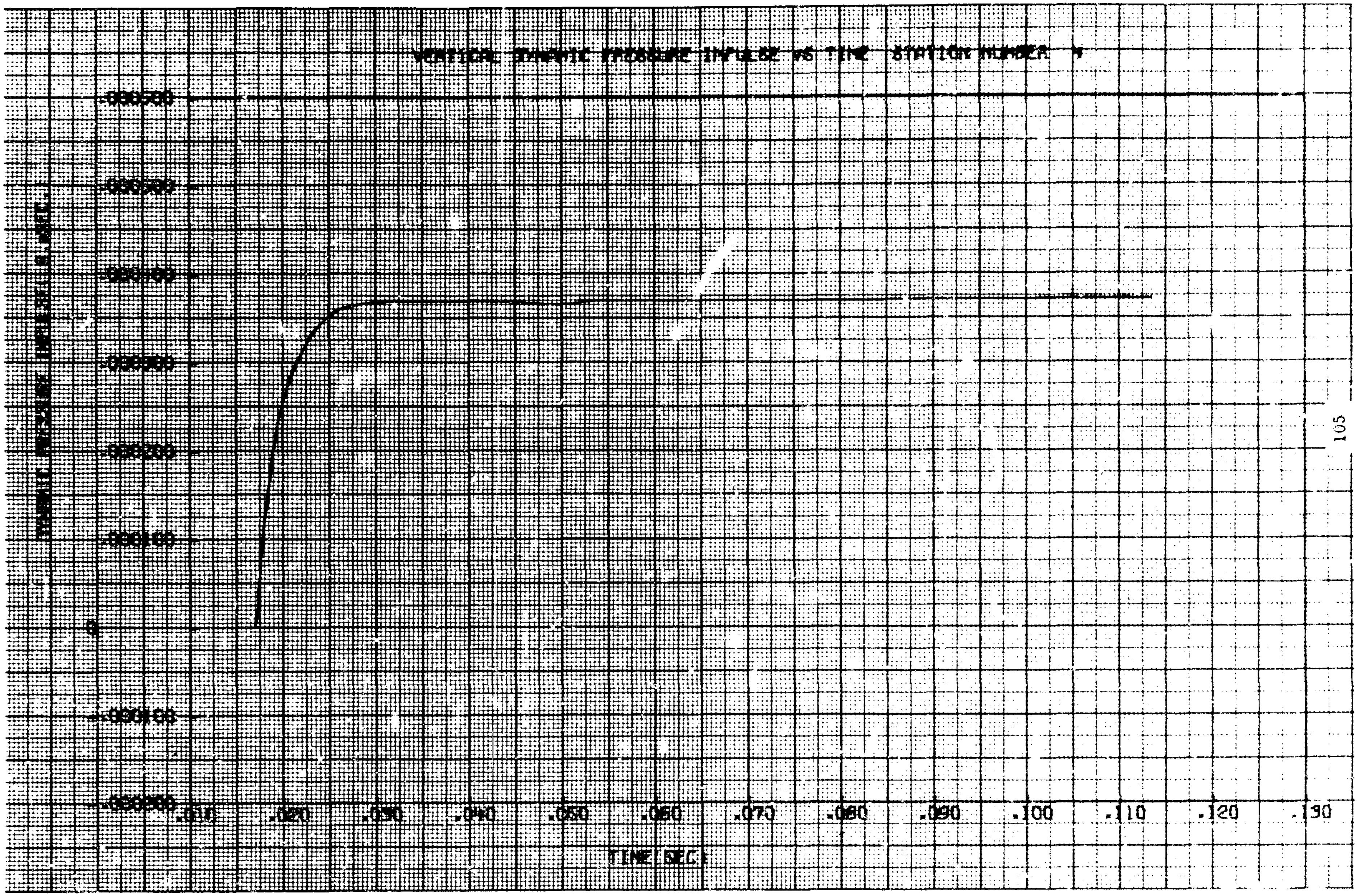

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER 4
120.00
100.00
80.00
60.00
40.00
20.00
0.
-20.00
-40.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

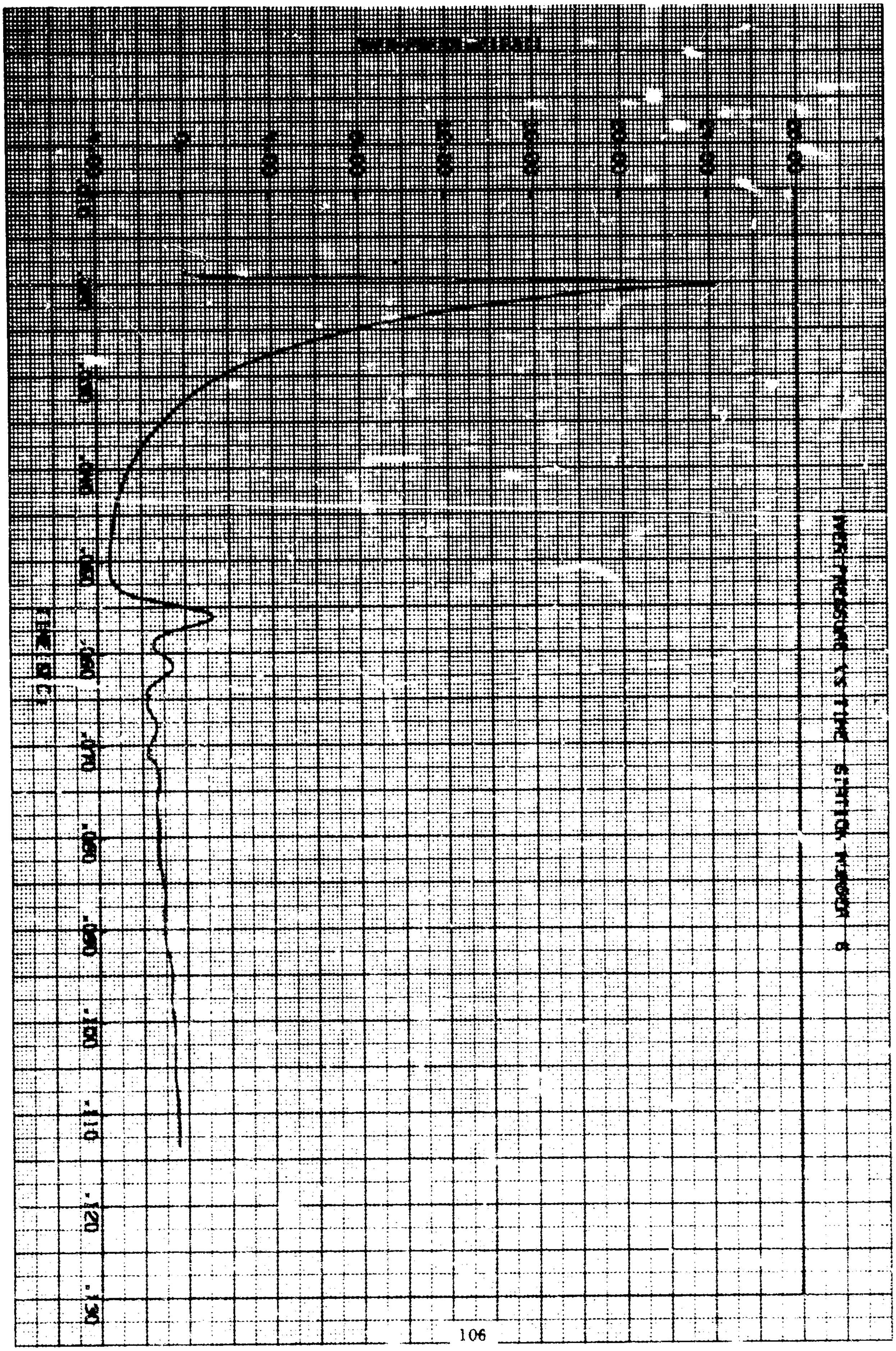


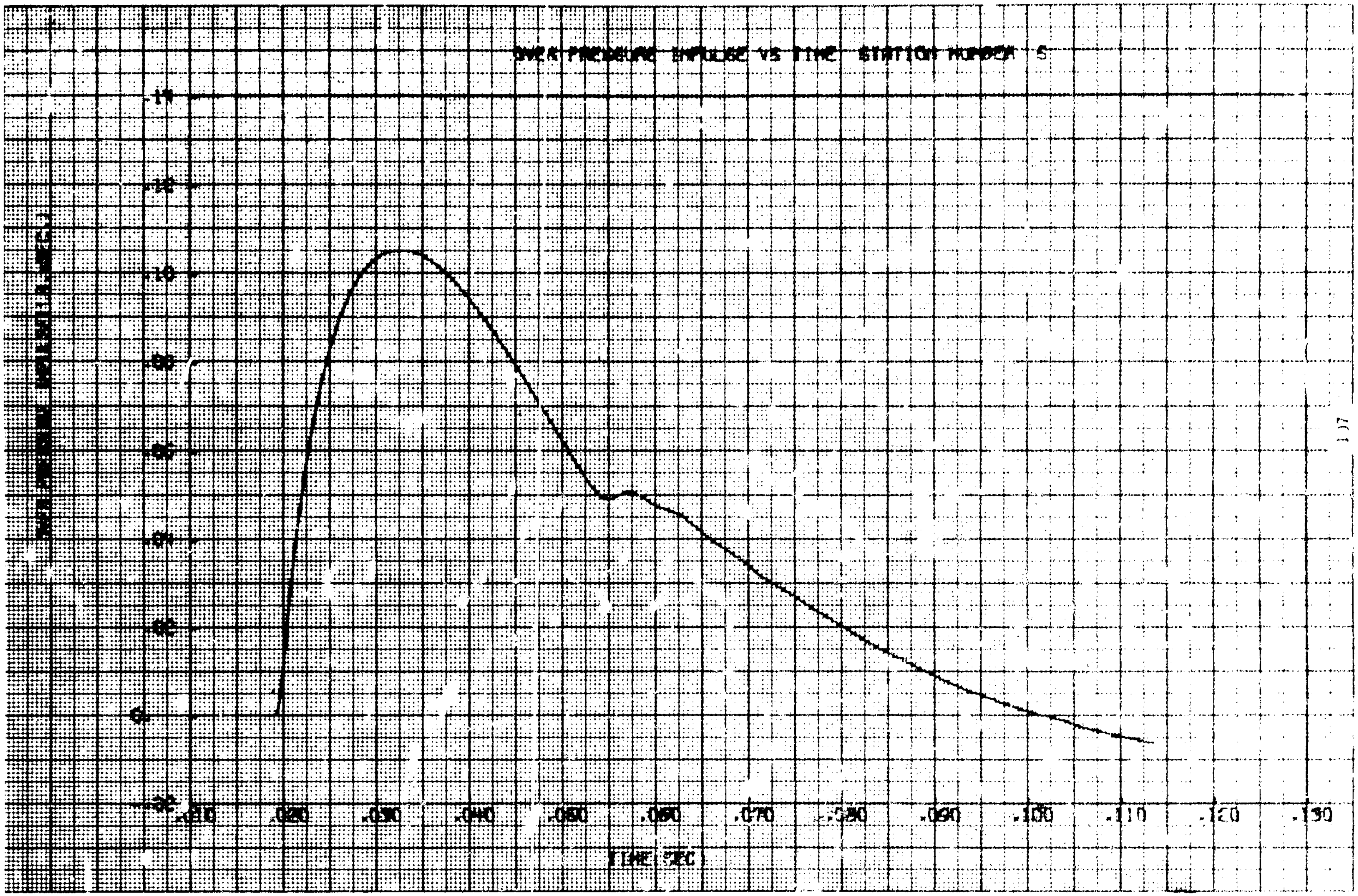
HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

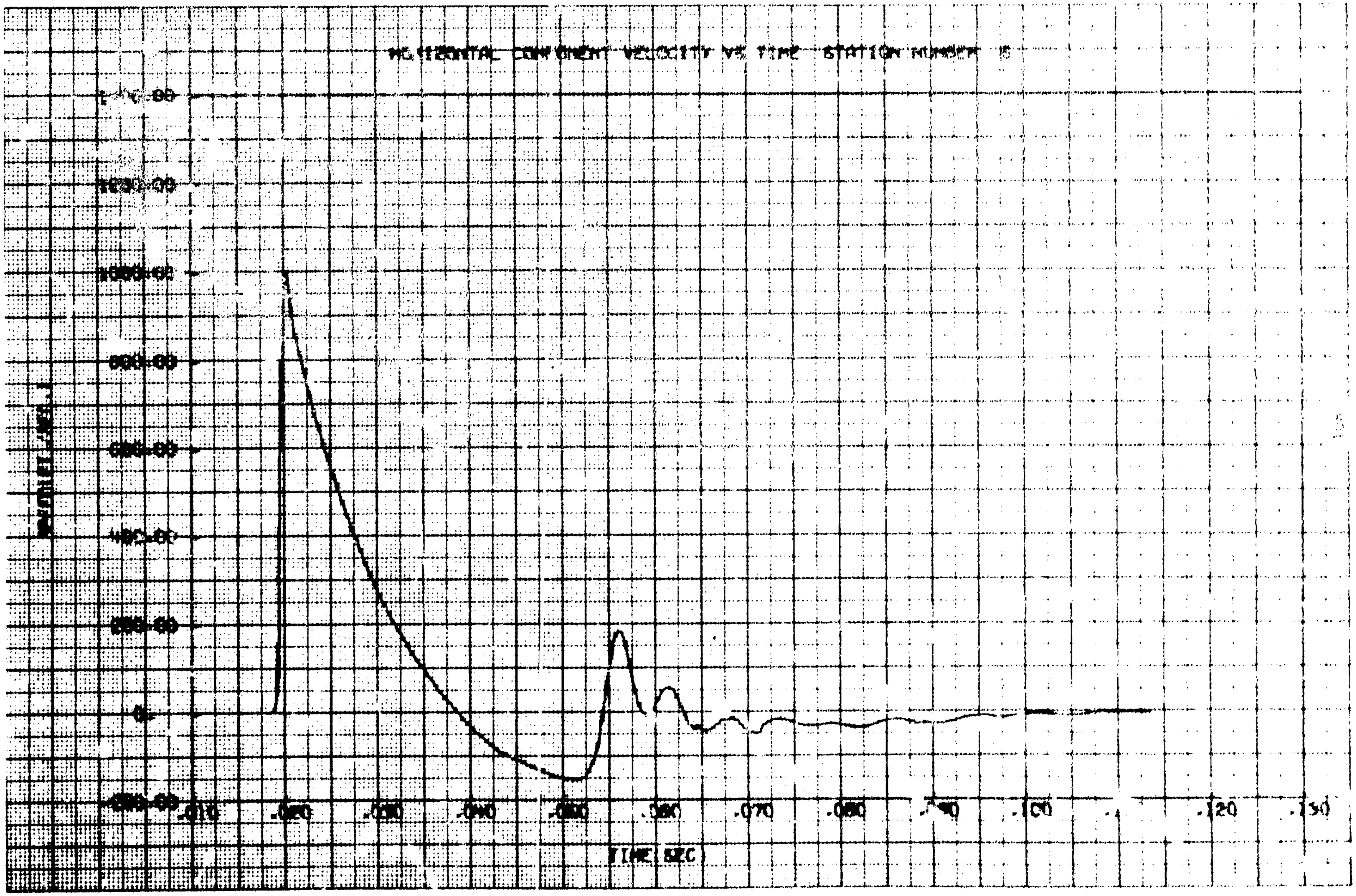

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 4
.070000
.060000
.050000
.040000
.030000
.020000
.010000
0
-.010000
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)


VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 4
DYNAMIC PRESSURE(PSI)
.24
.20
.16
.12
.08
.04
0.
-.04
-.08
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)

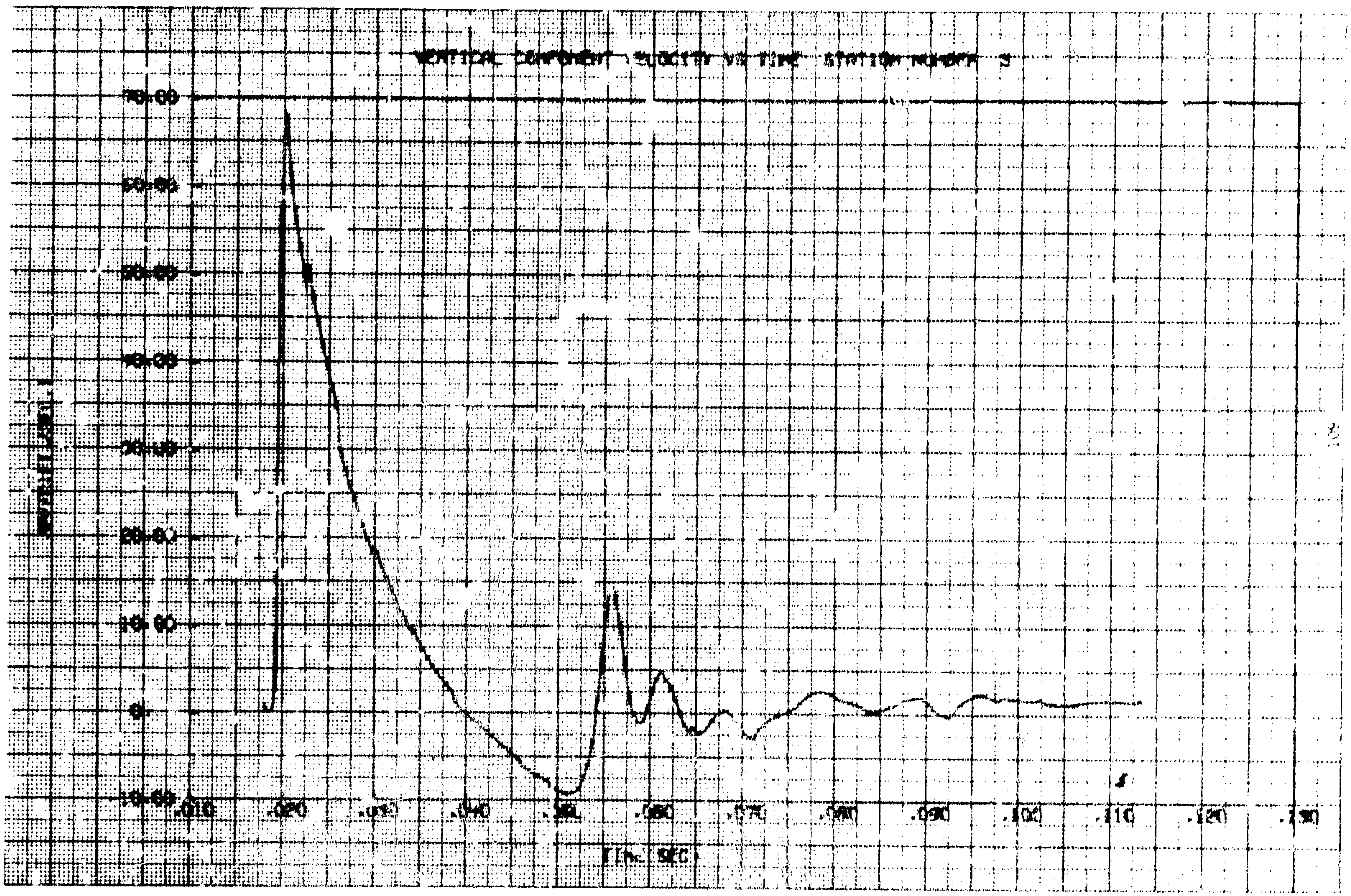

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

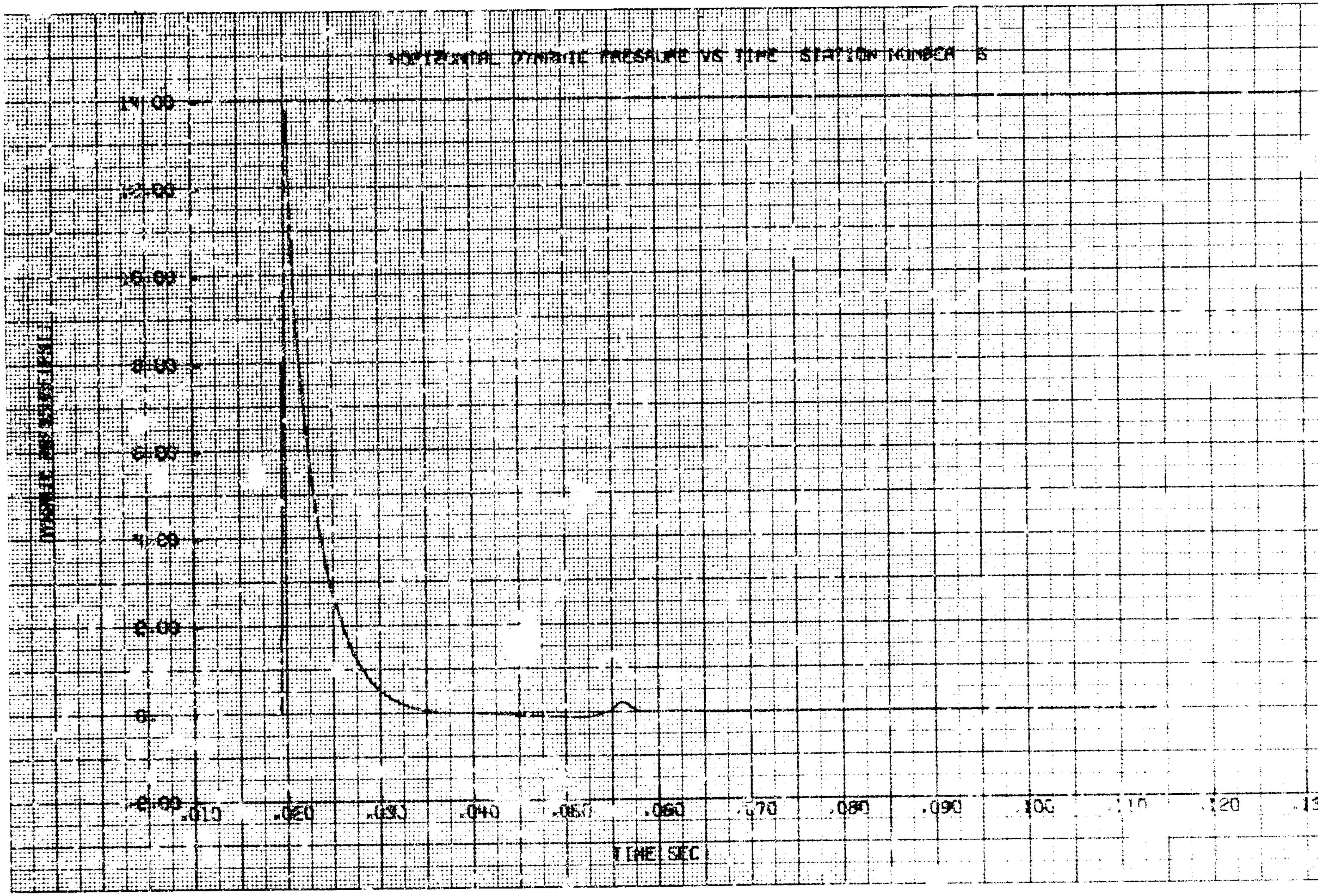

.070
.100
.110
.120
.130

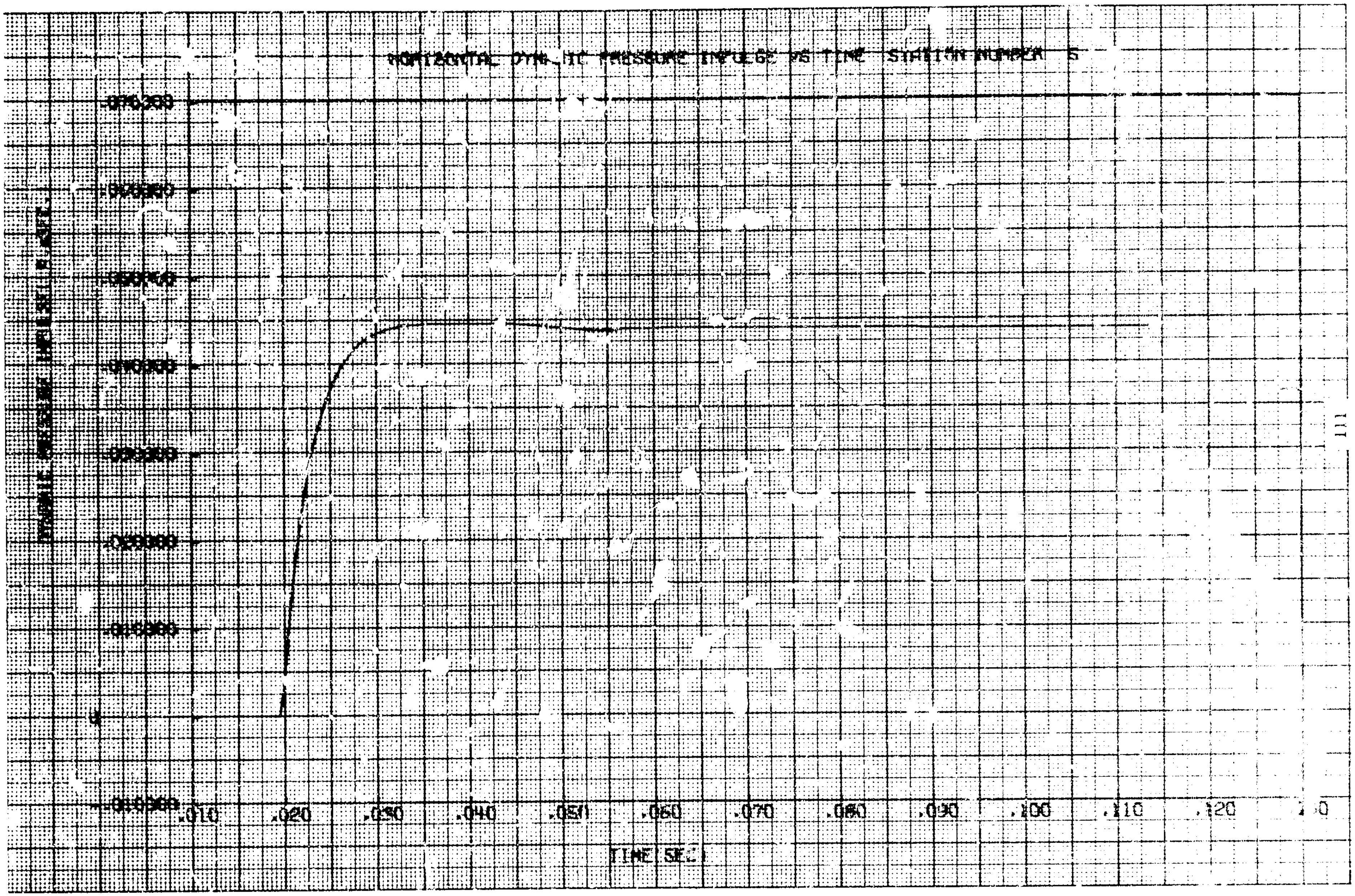

OVER PRESSURE IMPULSE VS TIME STATION NUMBER 5
TIME (SEC)

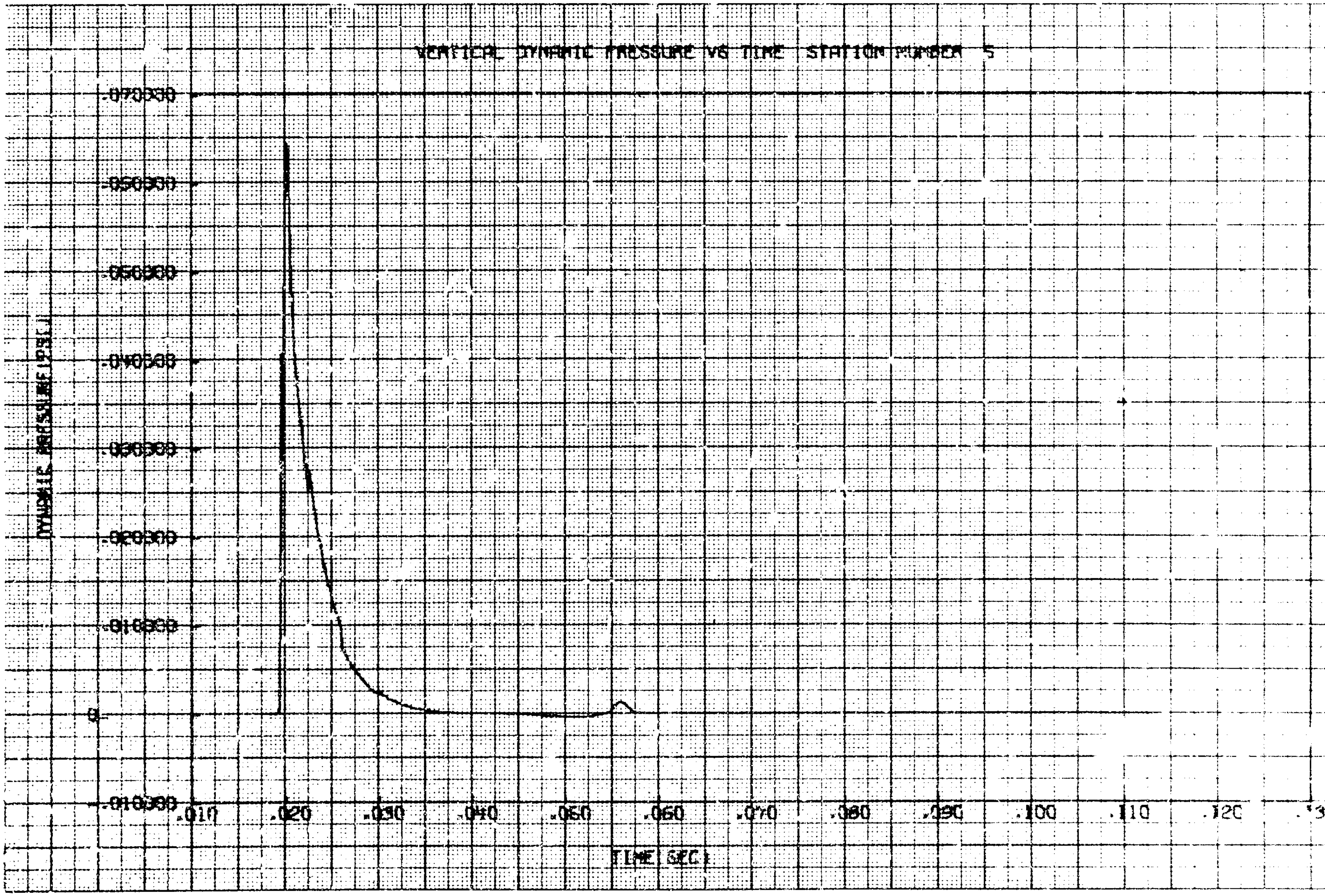


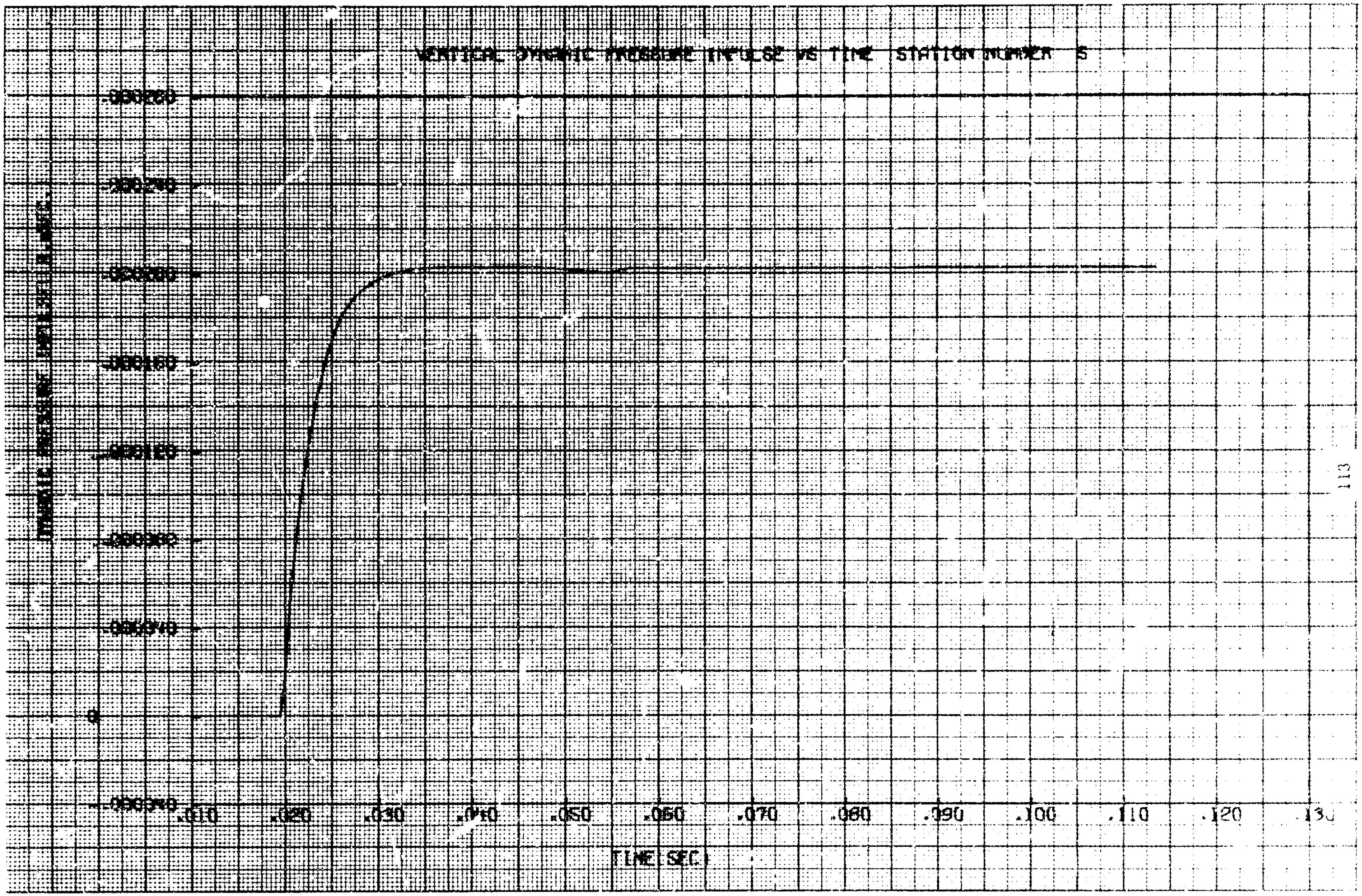
HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER
.070
.080
.120
TIME SEC

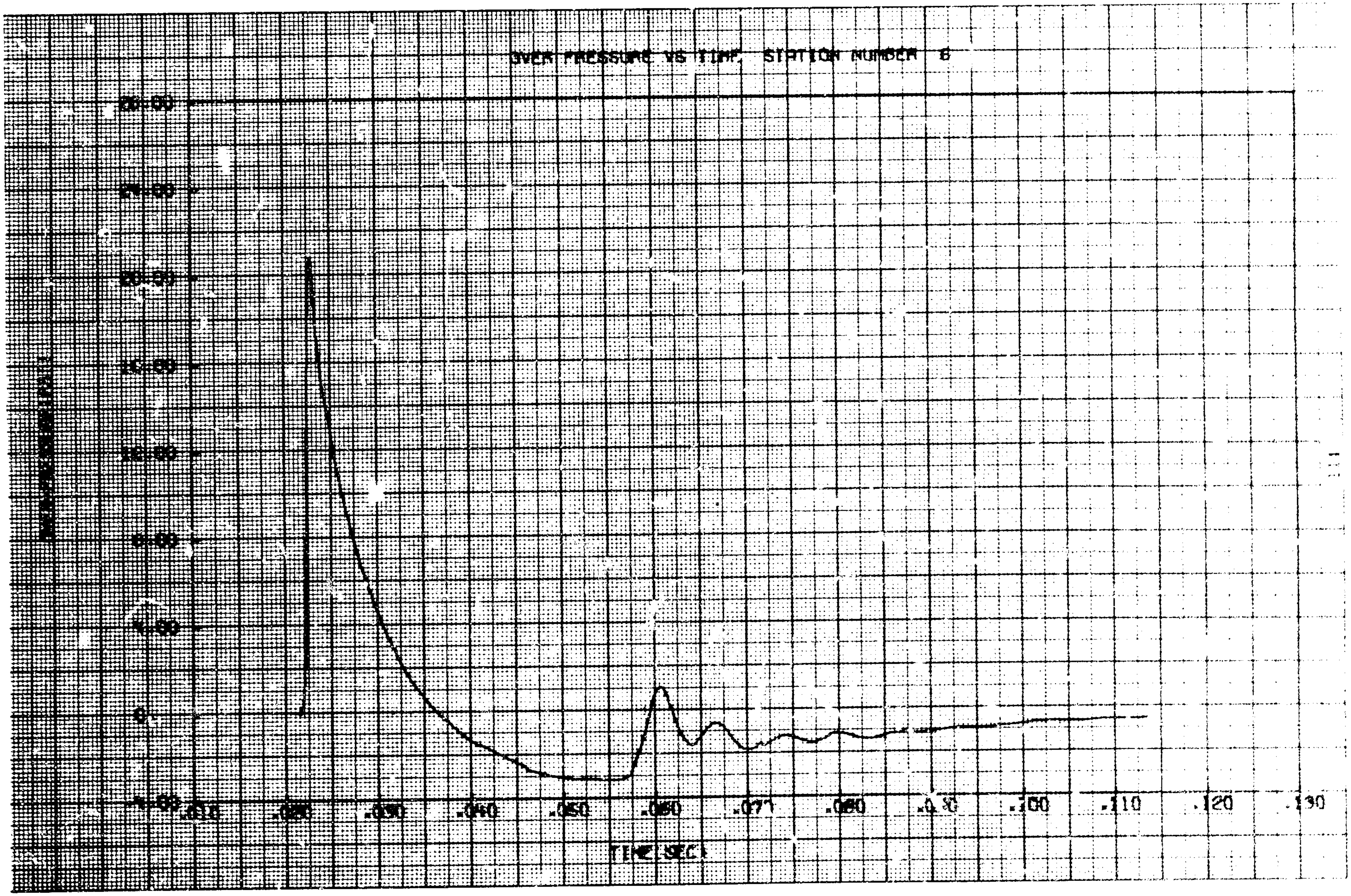

70.00
60.00
50.00
40.00
30.00
20.00
10.00
0
-10.00
.010
.020
.040
.060
.090
.100
.110
.120
.130
TIME SEC

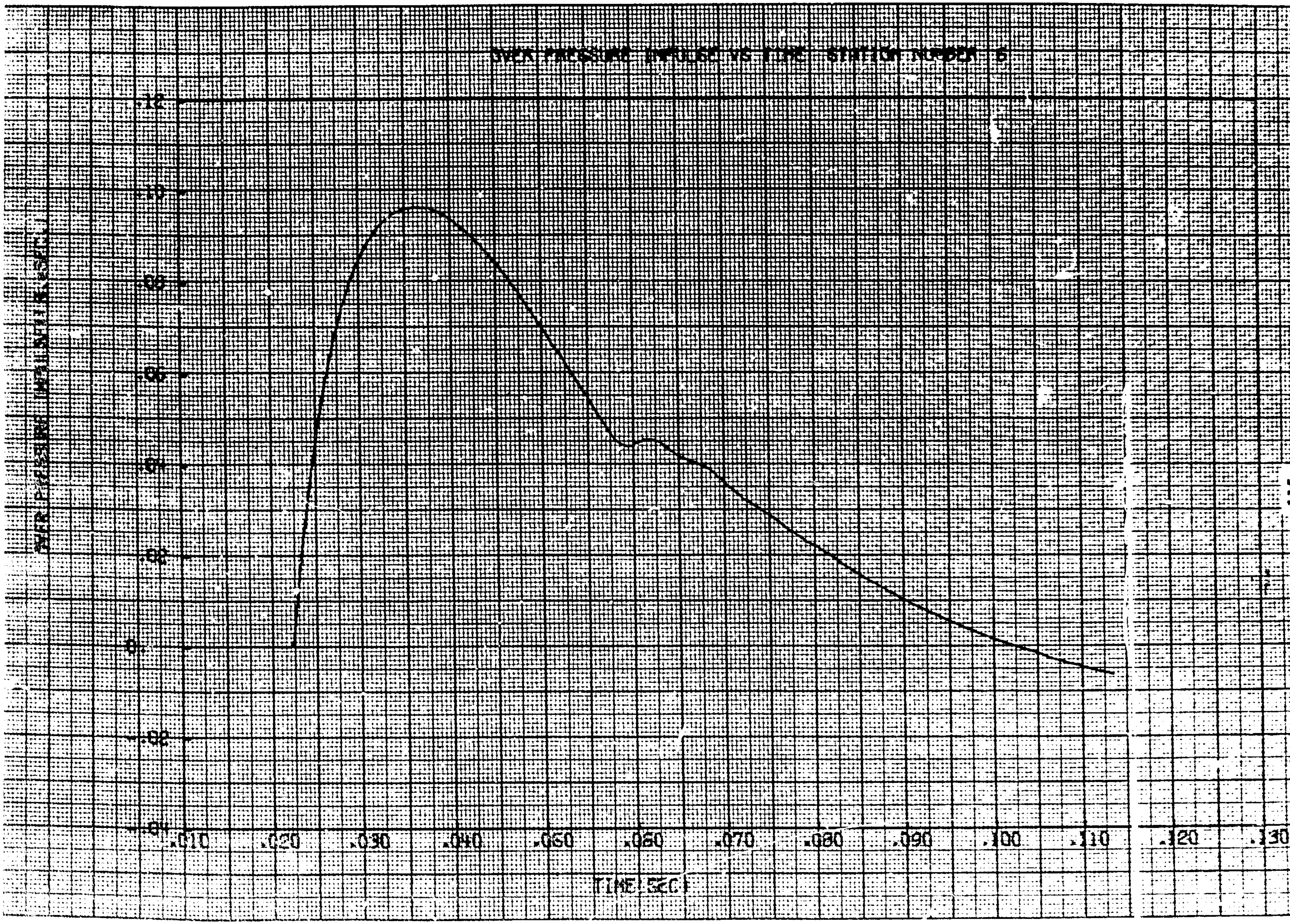

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 5
DYNAMIC PRESSURE (PSI)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.
-2.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

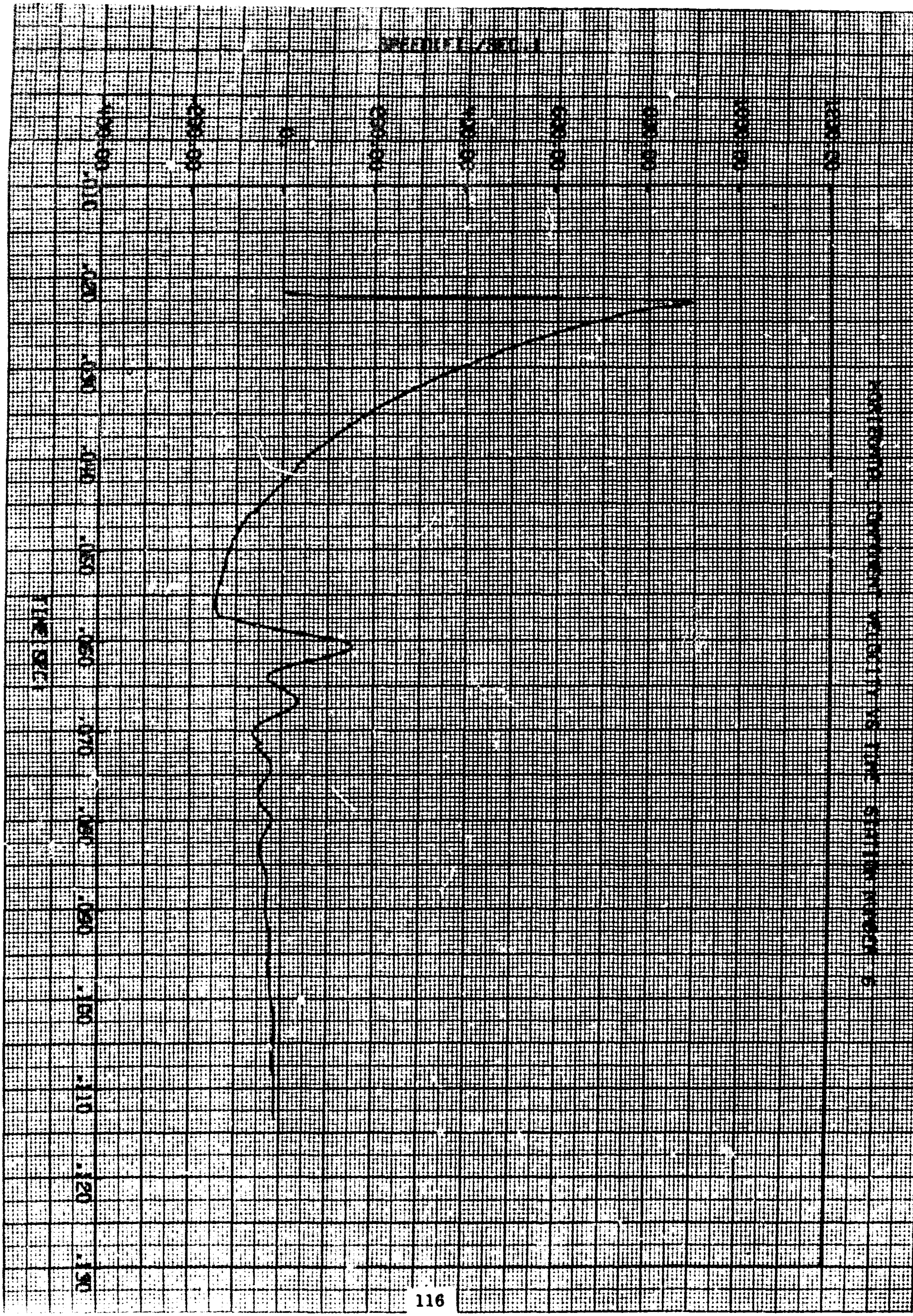

HORIZONTAL DYN IC PRESSURE IMPULSE VS TIME STATION NUMBER 5
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

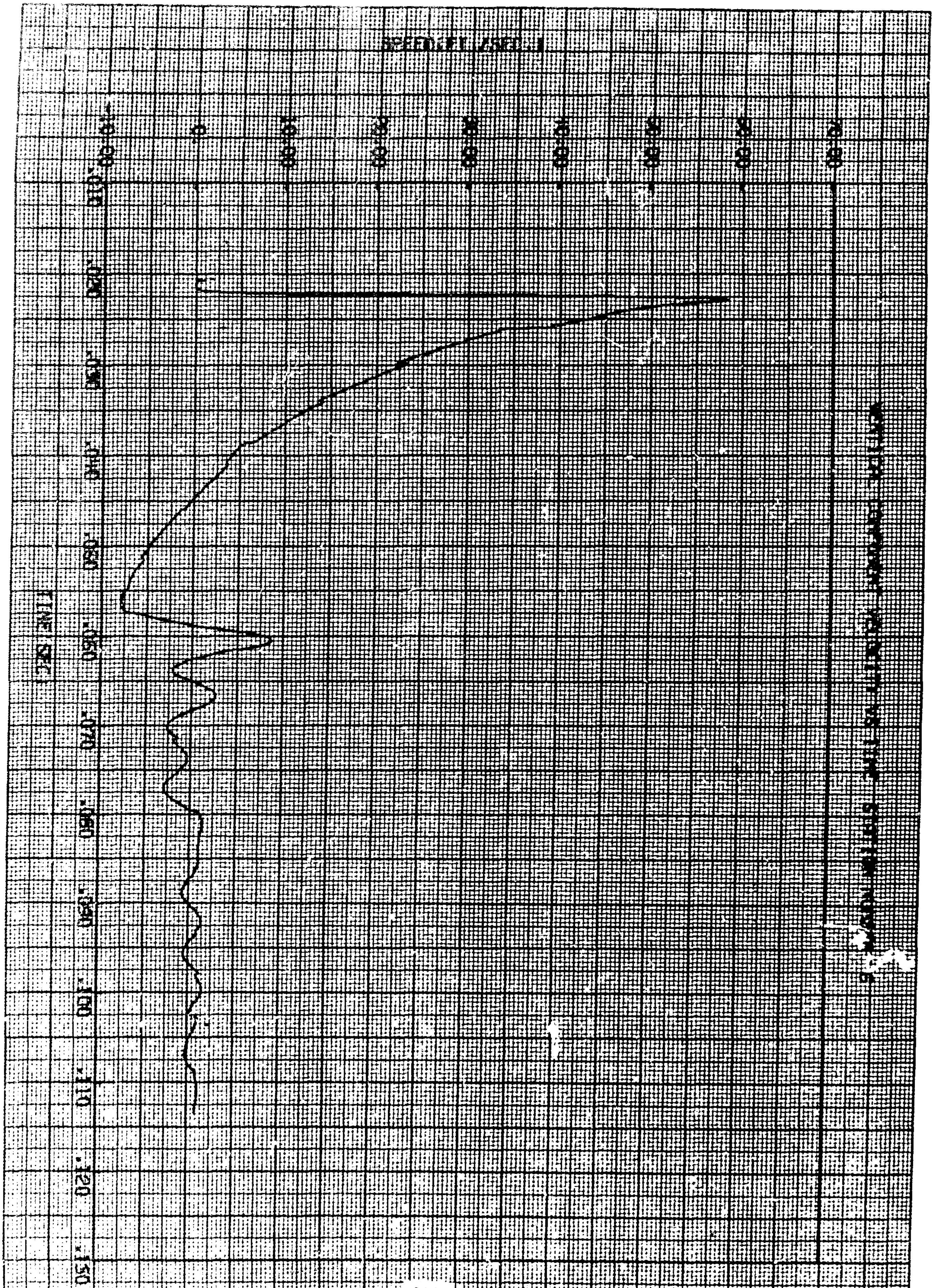

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 5
DYNAMIC PRESSURE(PSI)
.070000
.060000
.050000
.040000
.030000
.020000
.010000
0
-.010000
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

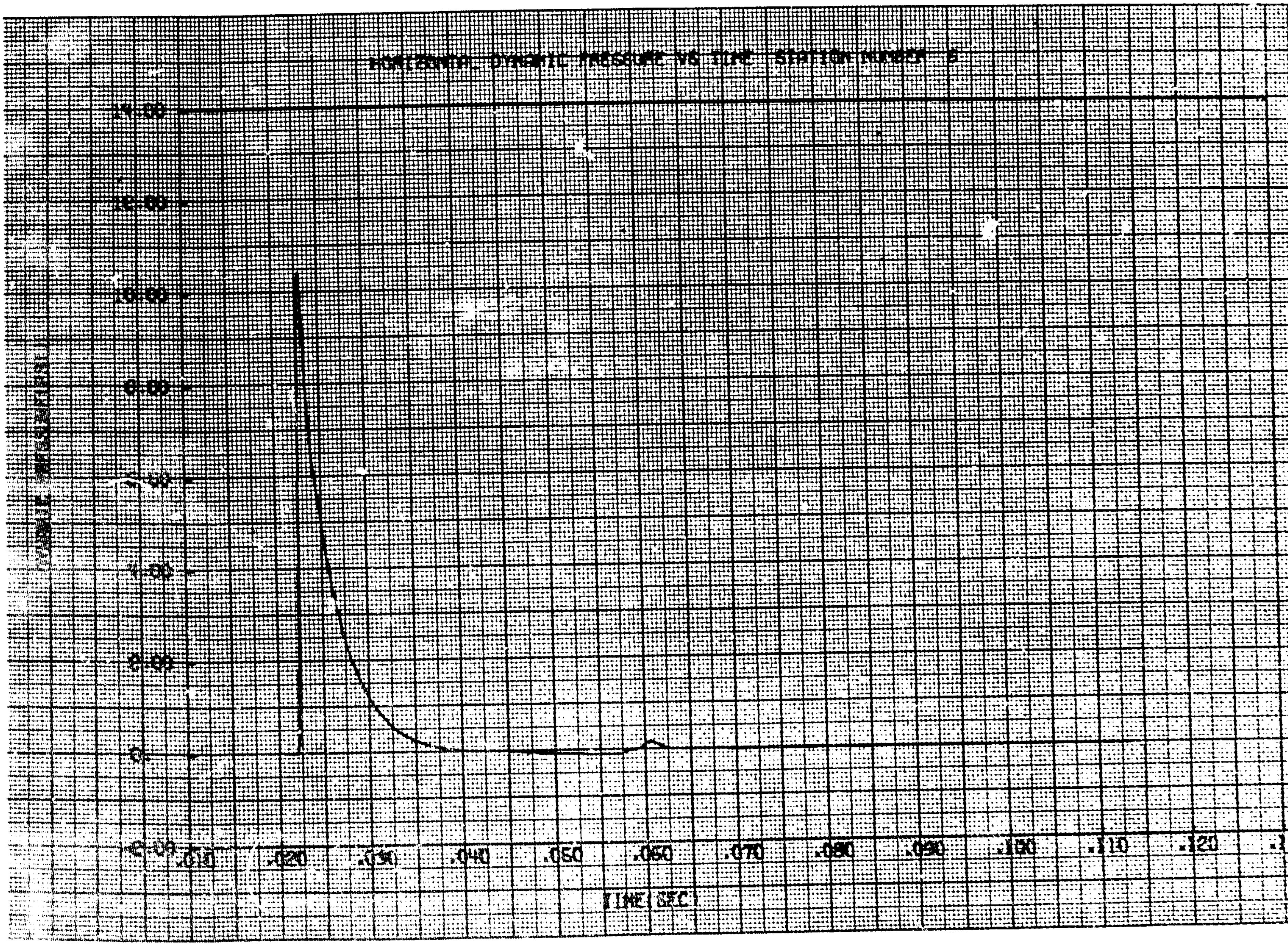

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 5
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

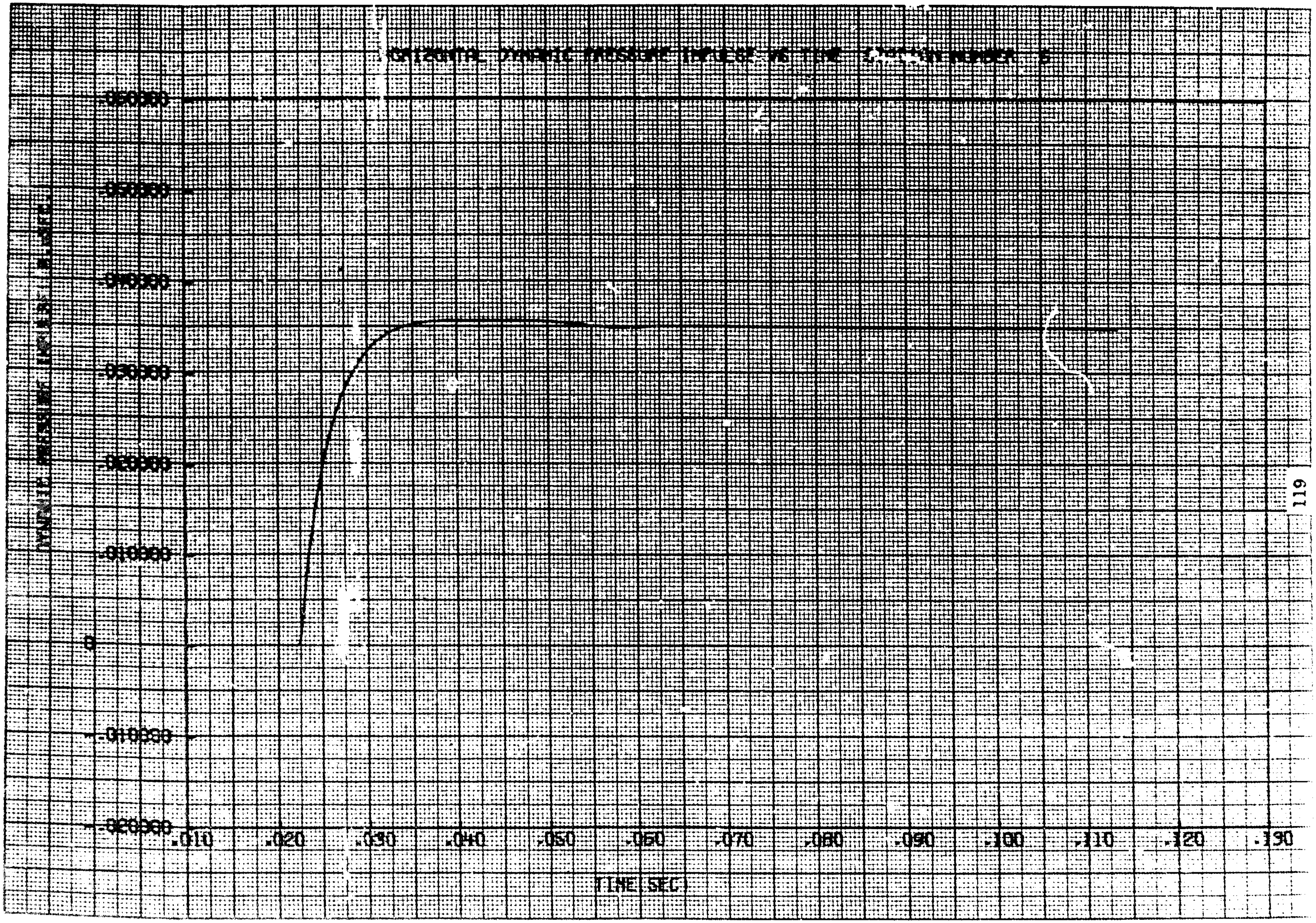

OVER PRESSURE VS TIME, STATION NUMBER 8
.030
.040
.050
.100
.110
.120
.130
TIME SEC


OVER PRESSURE IMPULSE VS TIME
TIME (SEC)

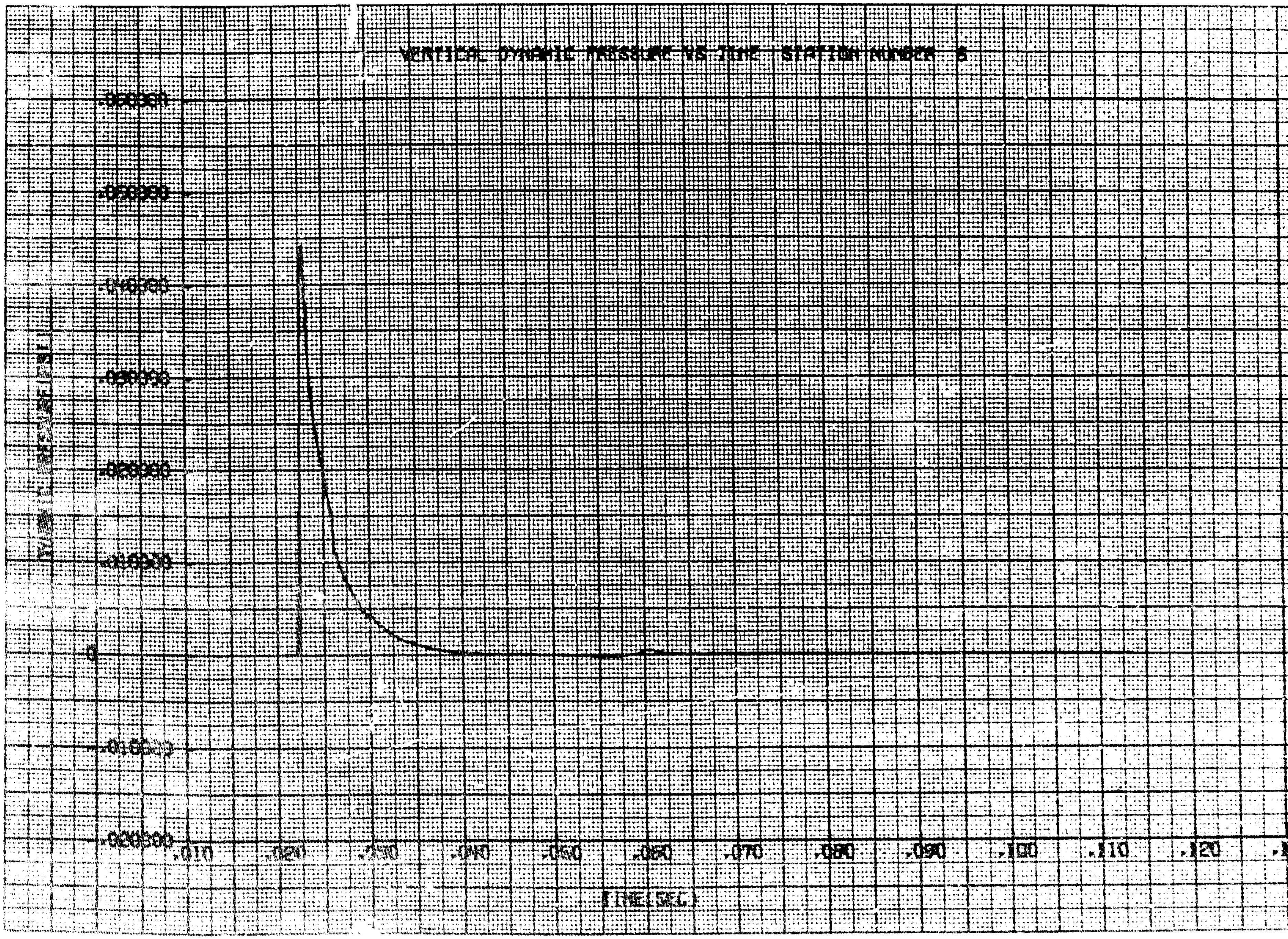

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 6
TIME(SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
1200.00
1000.00
800.00
600.00
400.00
200.00
0.
-200.00
-400.00

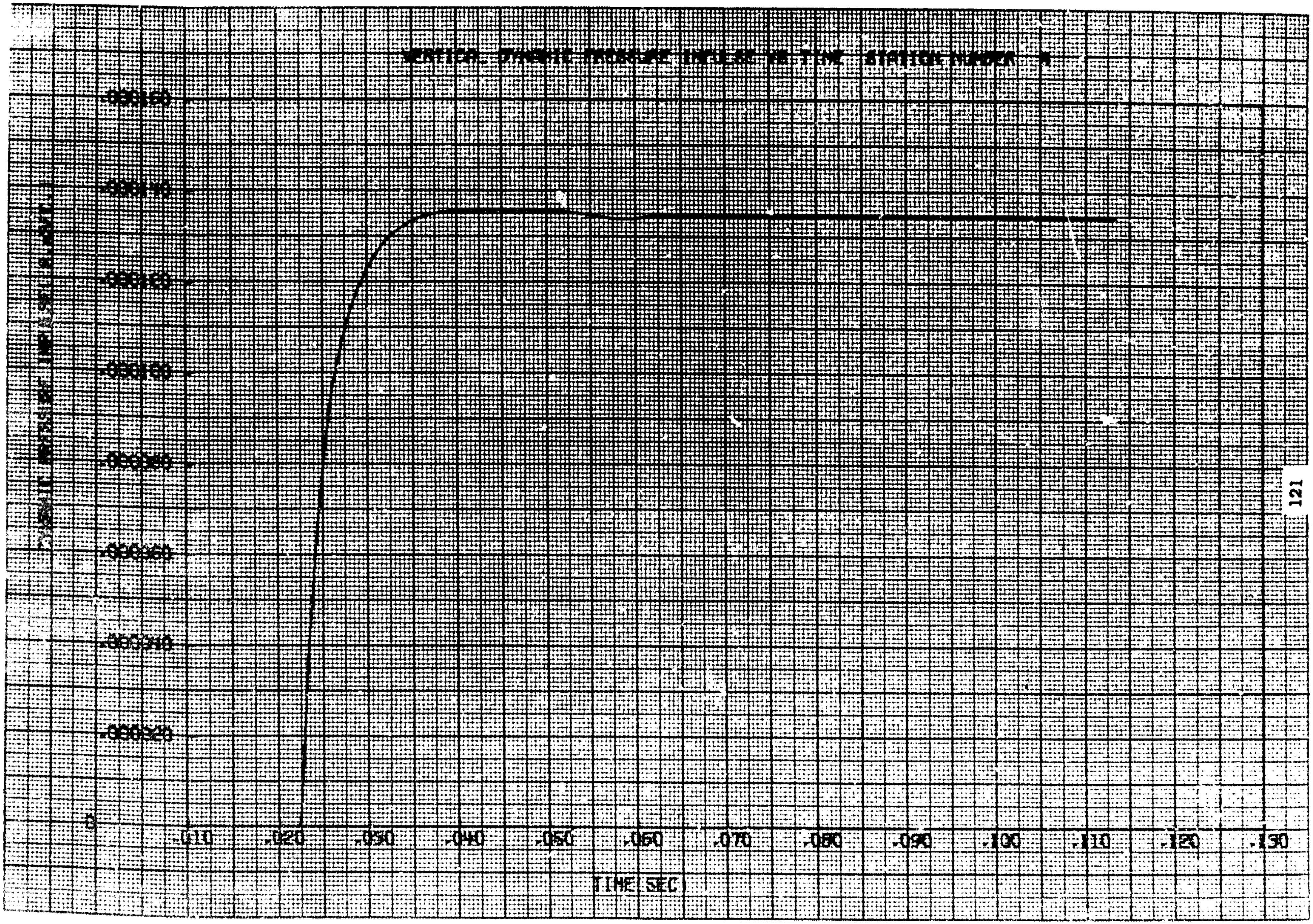

VERTICAL COMPONENT VELOCITY VS TIME STATION NO
SPEED(FT/SEC)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0
-10.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.150
TIME(SEC)

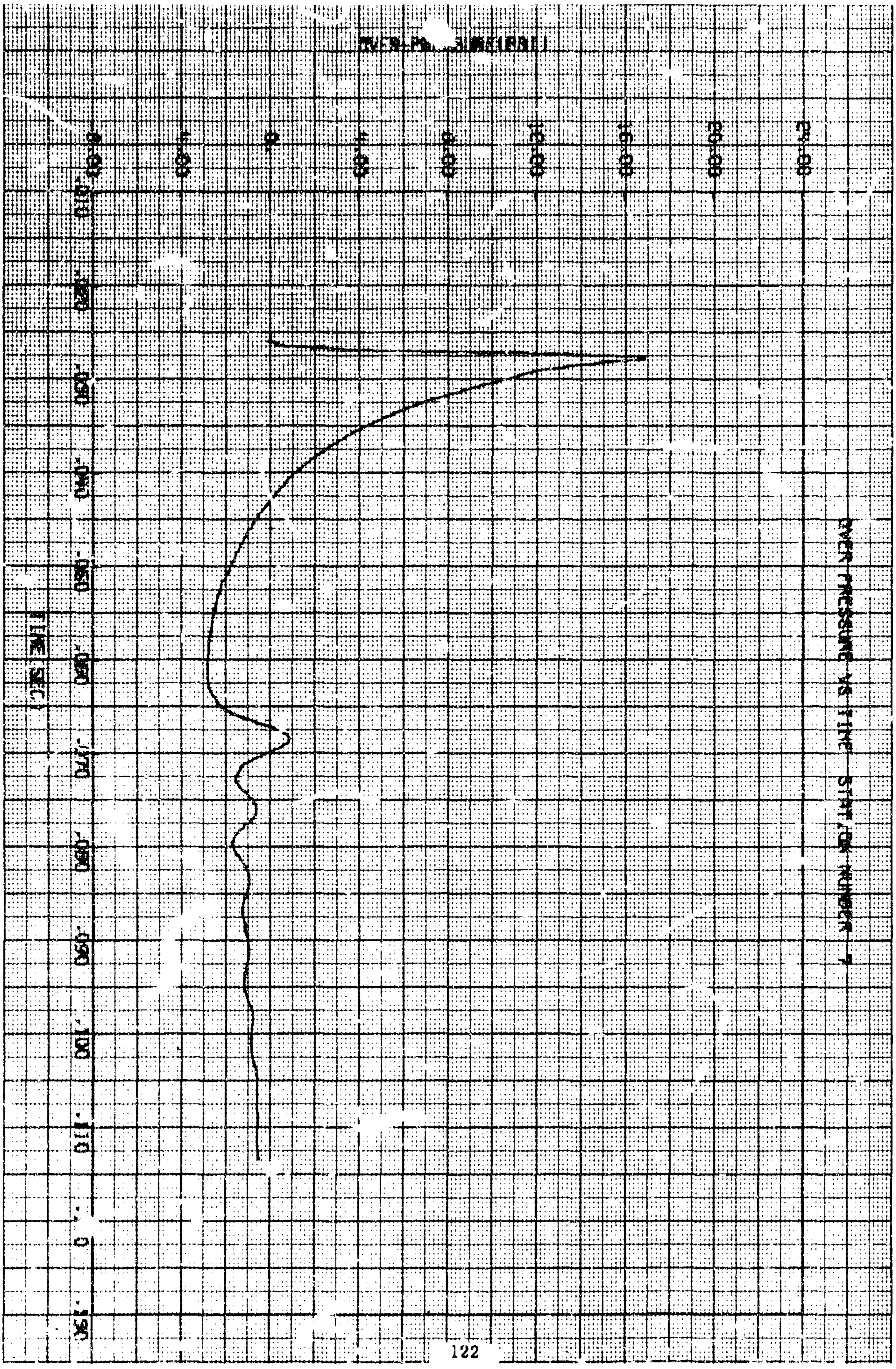

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

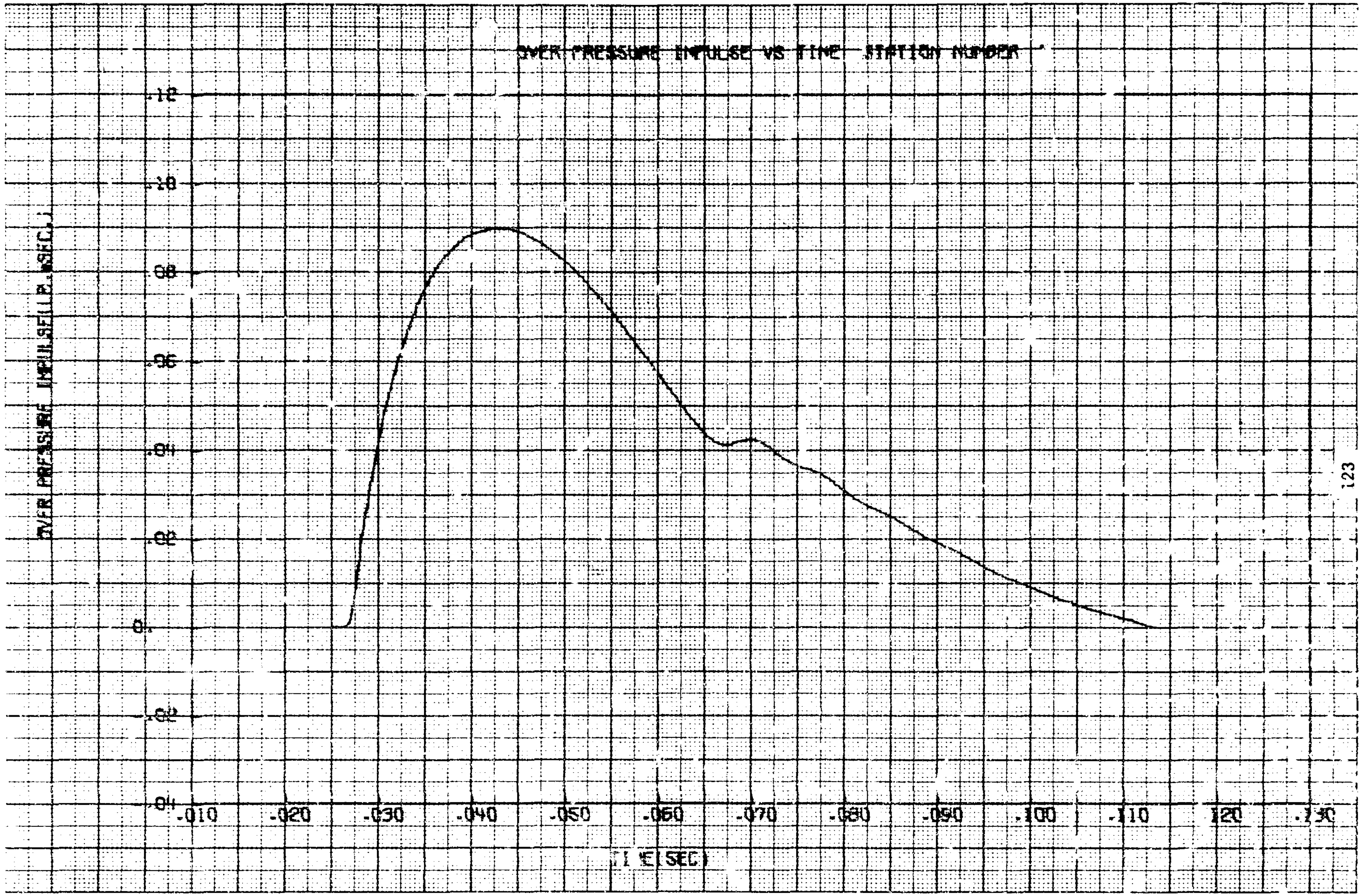


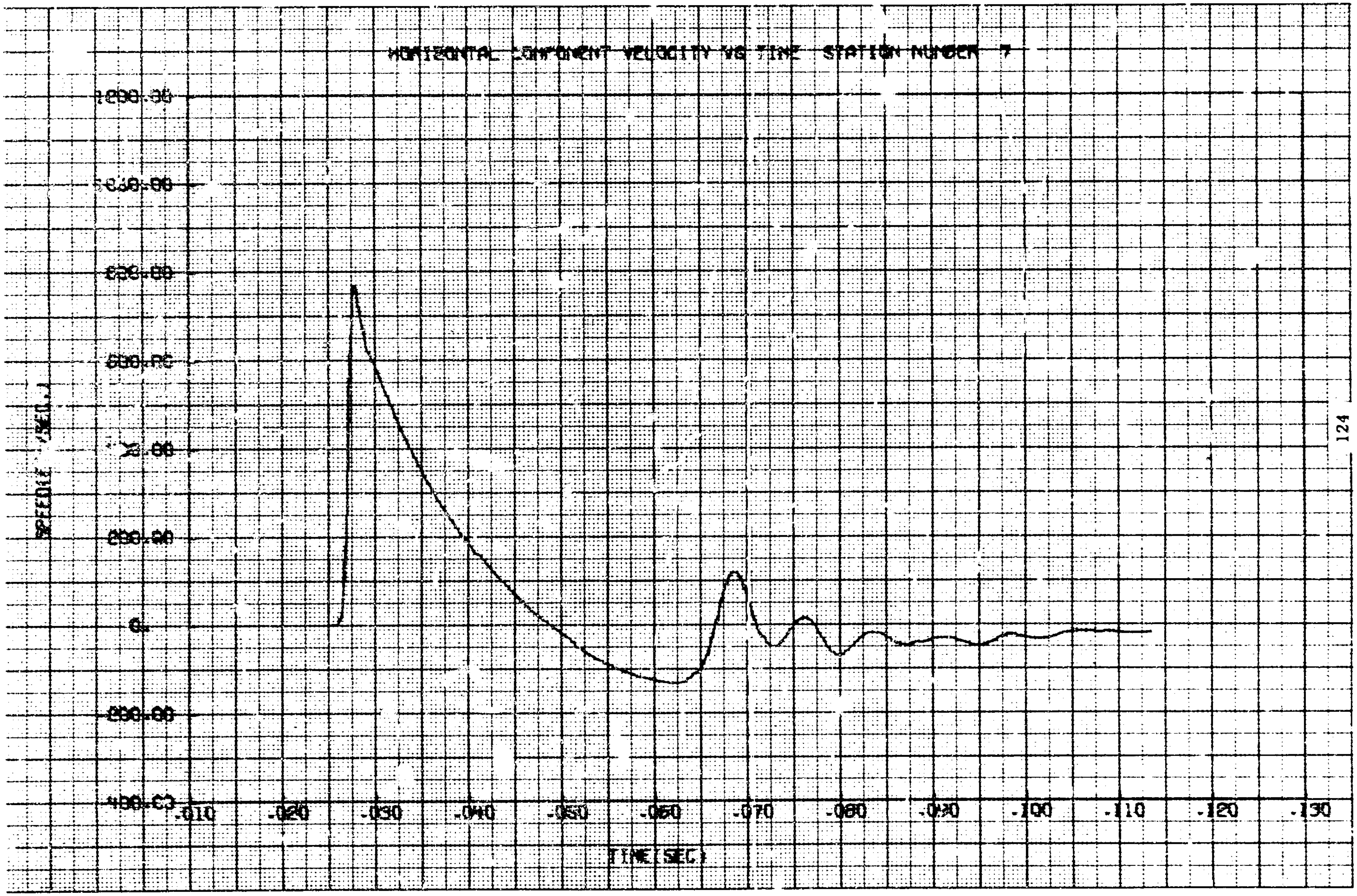
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

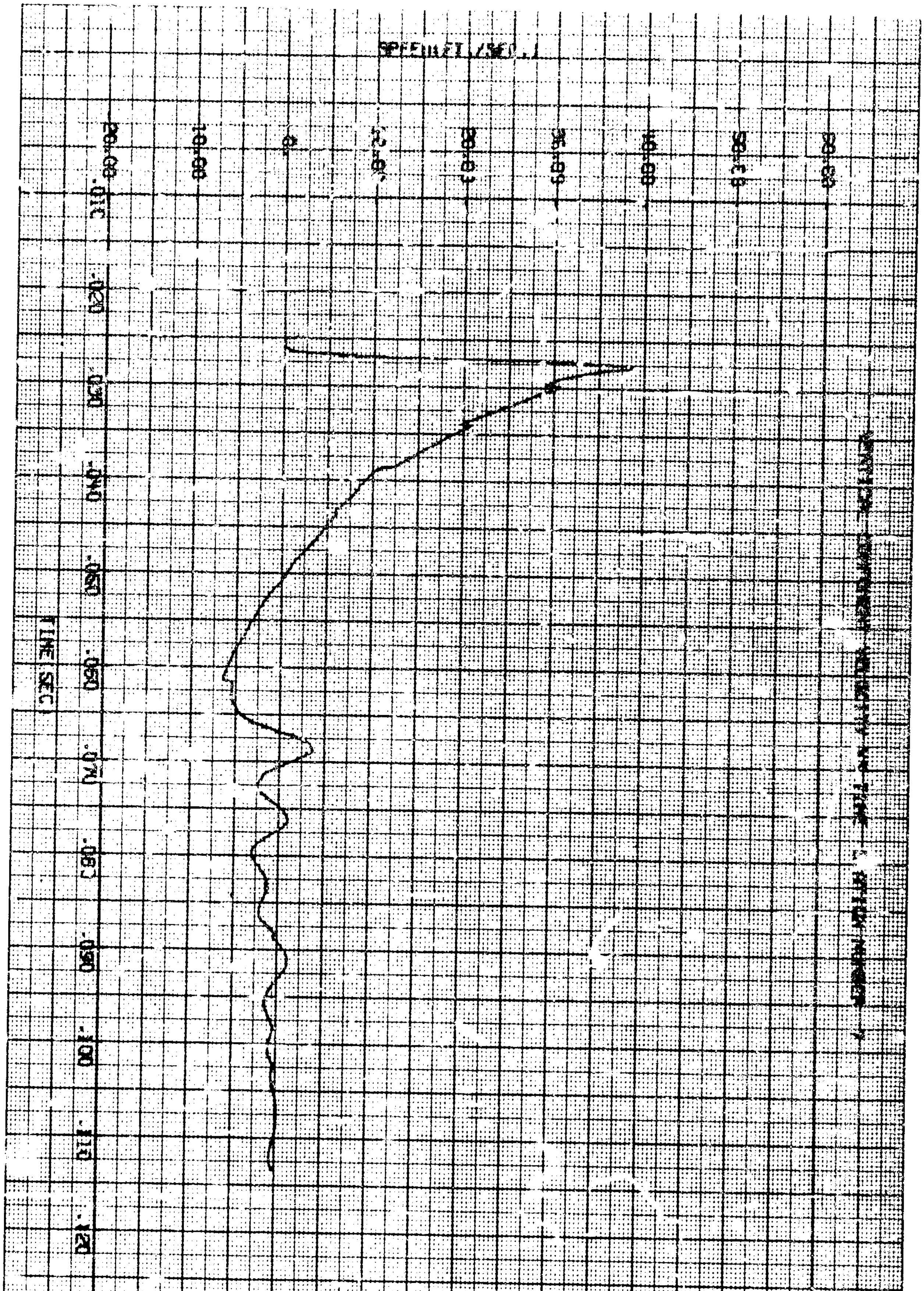

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER
.060000
.050000
.040000
.030000
.020000
.010000
0
-.010000
-.020000
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

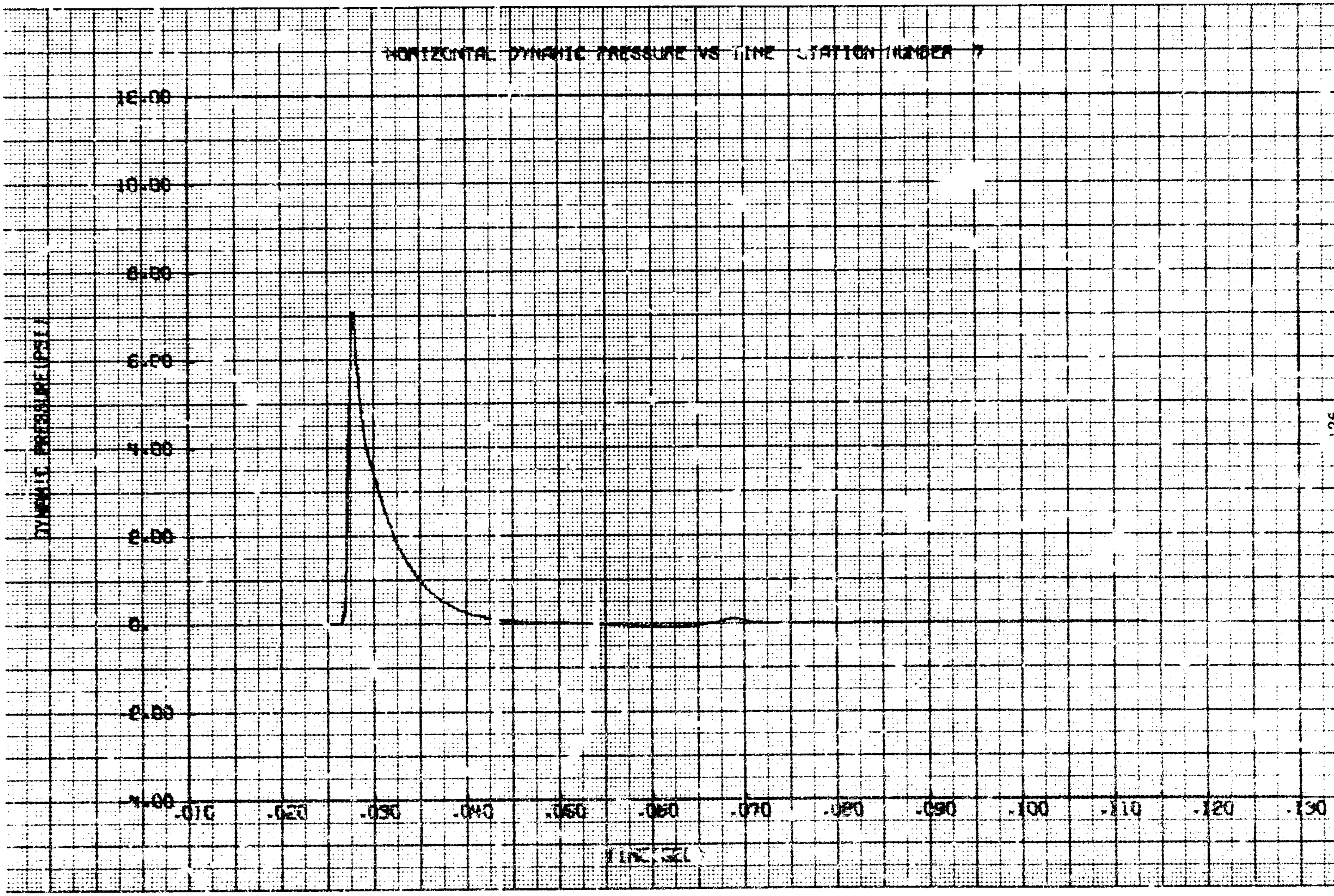

0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

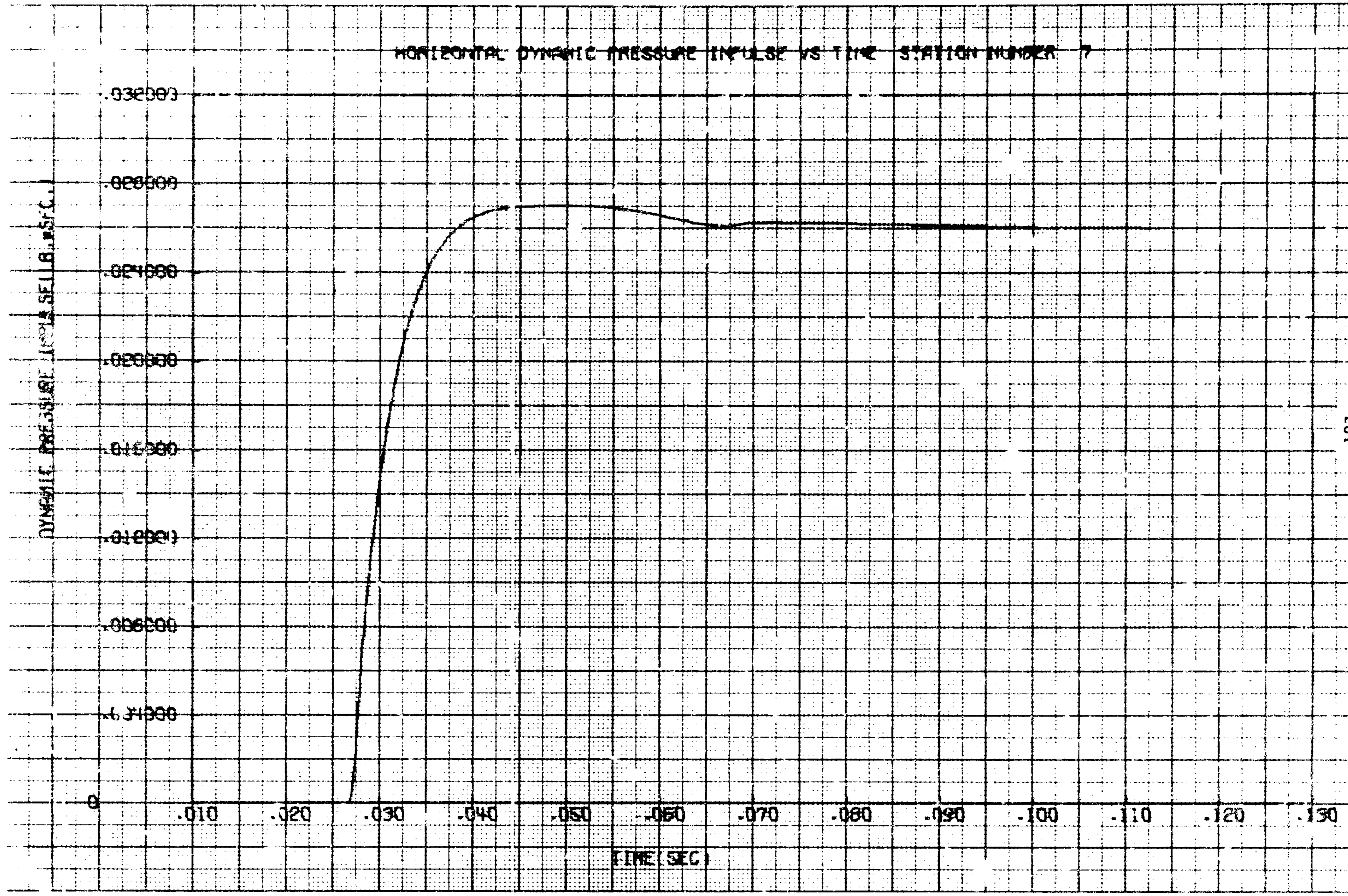

OVER PRESSURE VS TIME STATION NUMBER 7
24.00
20.00
16.00
12.00
8.00
4.00
0.
-4.00
-8.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.130
TIME(SEC)

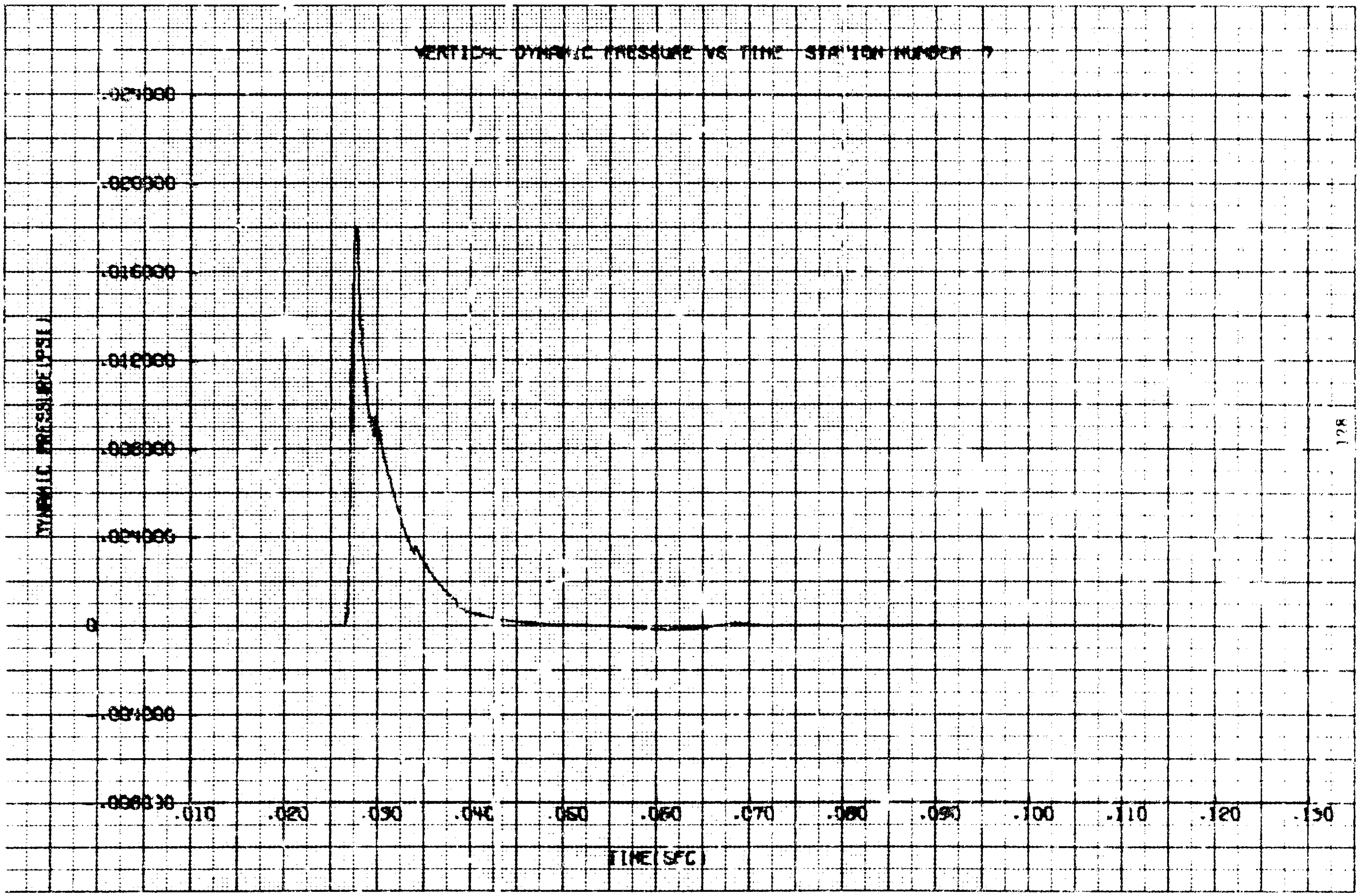

OVER PRESSURE IMPULSE VS TIME STATION NUMBER
OVER PRESSURE IMPULSE(LB.-SEC.)
.12
.10
.08
.06
.04
.02
0.
-.02
-.04
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)


HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 7
200.00
0.
TIME(SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.100
.110
.120
.130

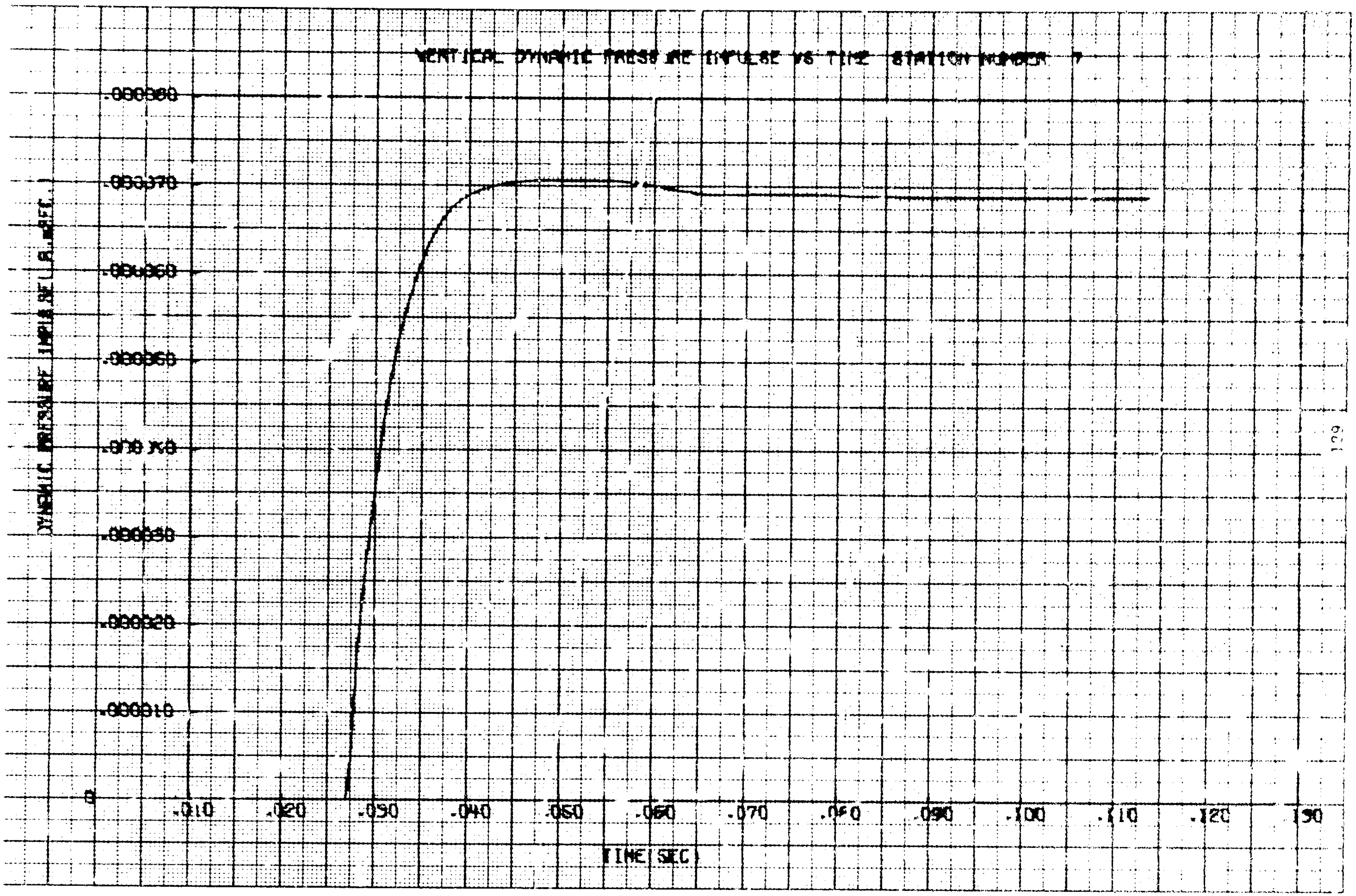

SPEED(FT./SEC.)
TIME SEC)


HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 7
DYNAMIC PRESSURE(PSI)
12.00
10.00
8.00
6.00
4.00
2.00
0.
-2.00
-4.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)

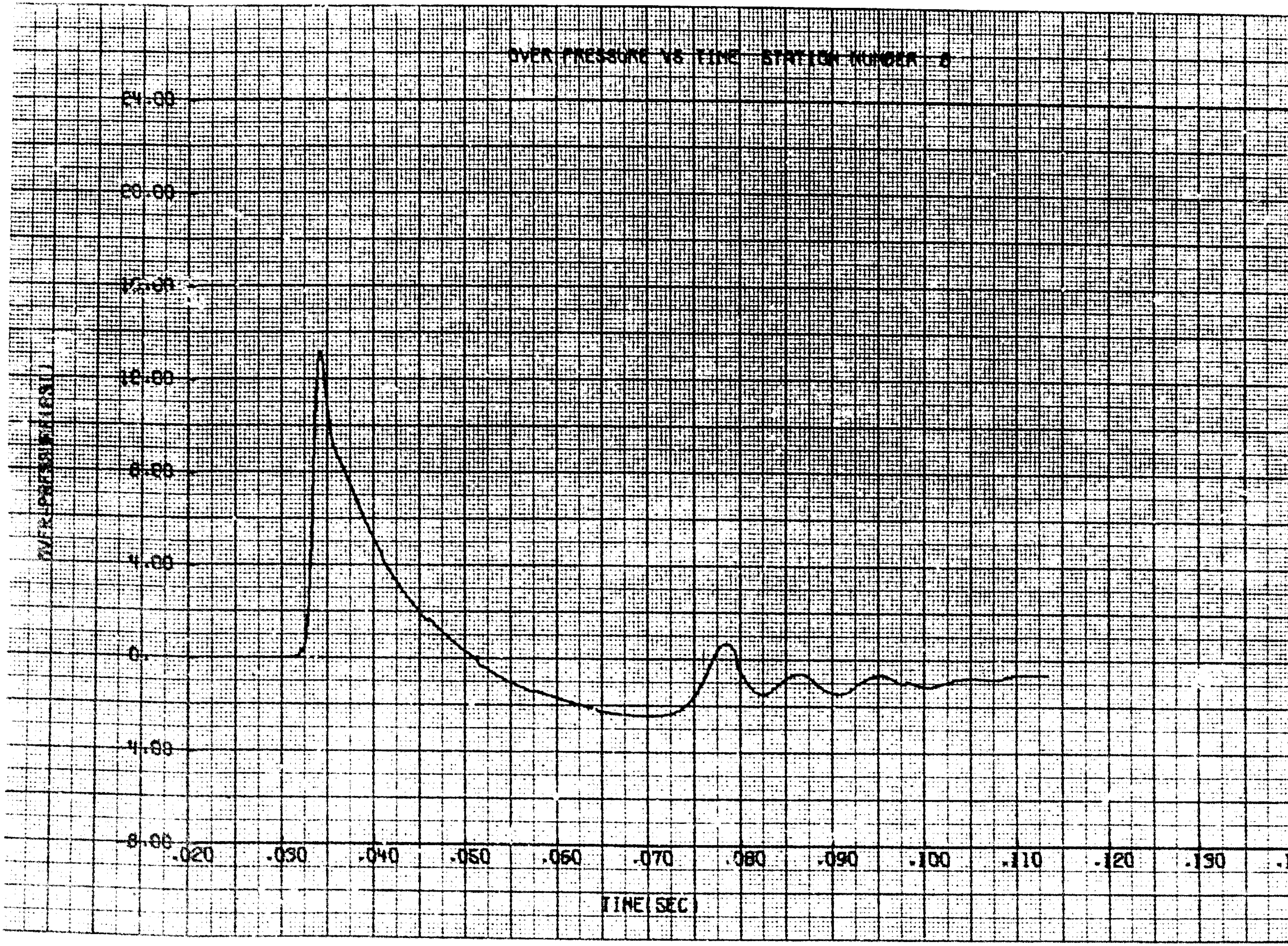

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 7
DYNAMIC PRESSURE IMPULSE(LB.-SEC.)
.032000
.028000
.024000
.020000
.016000
.012000
.008000
.004000
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)

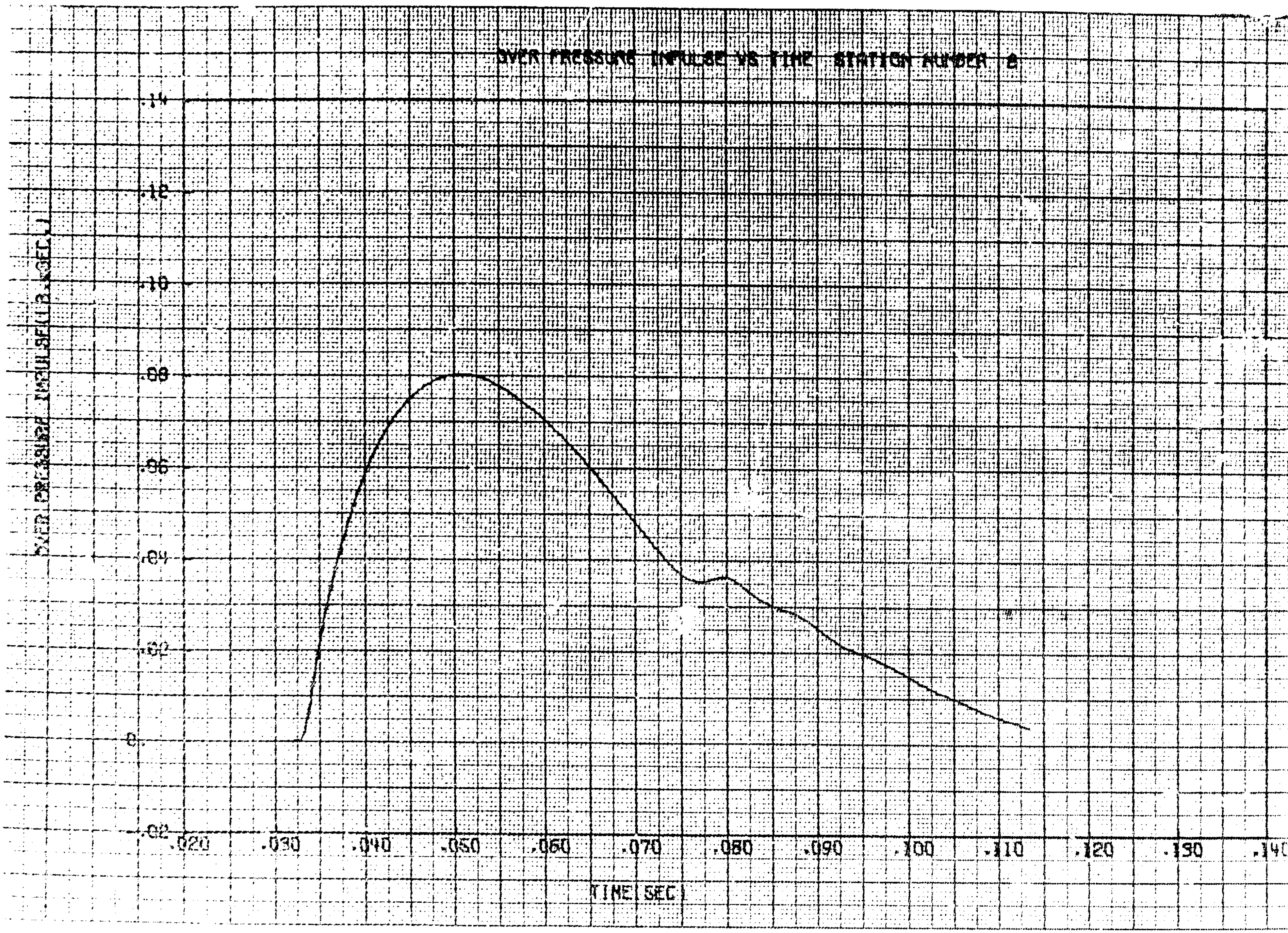


VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 7
DYNAMIC PRESSURE(PSI)
.024000
.020000
.016000
.012000
.008000
.004000
0
-.004000
-.008000
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME(SEC)

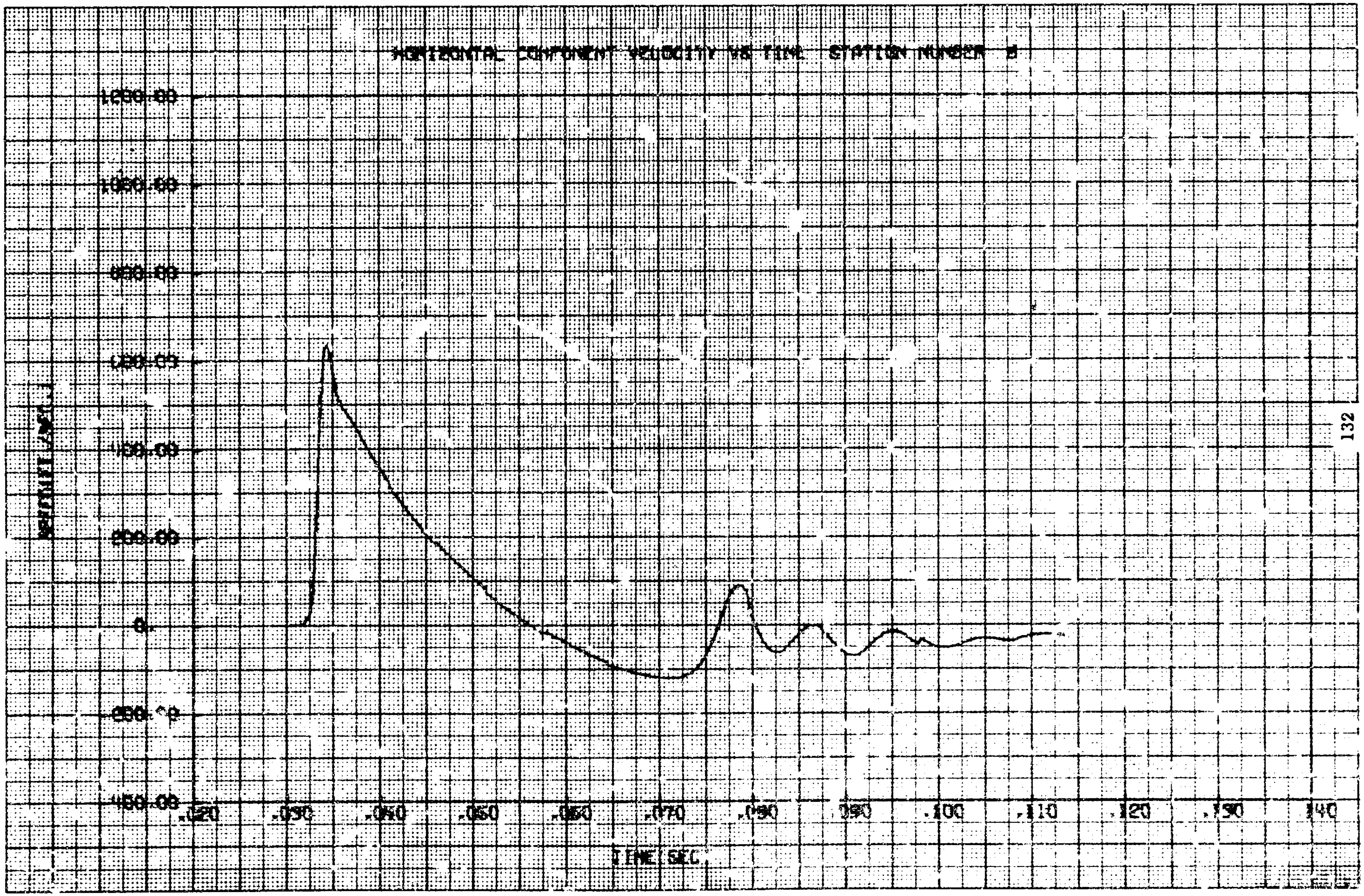


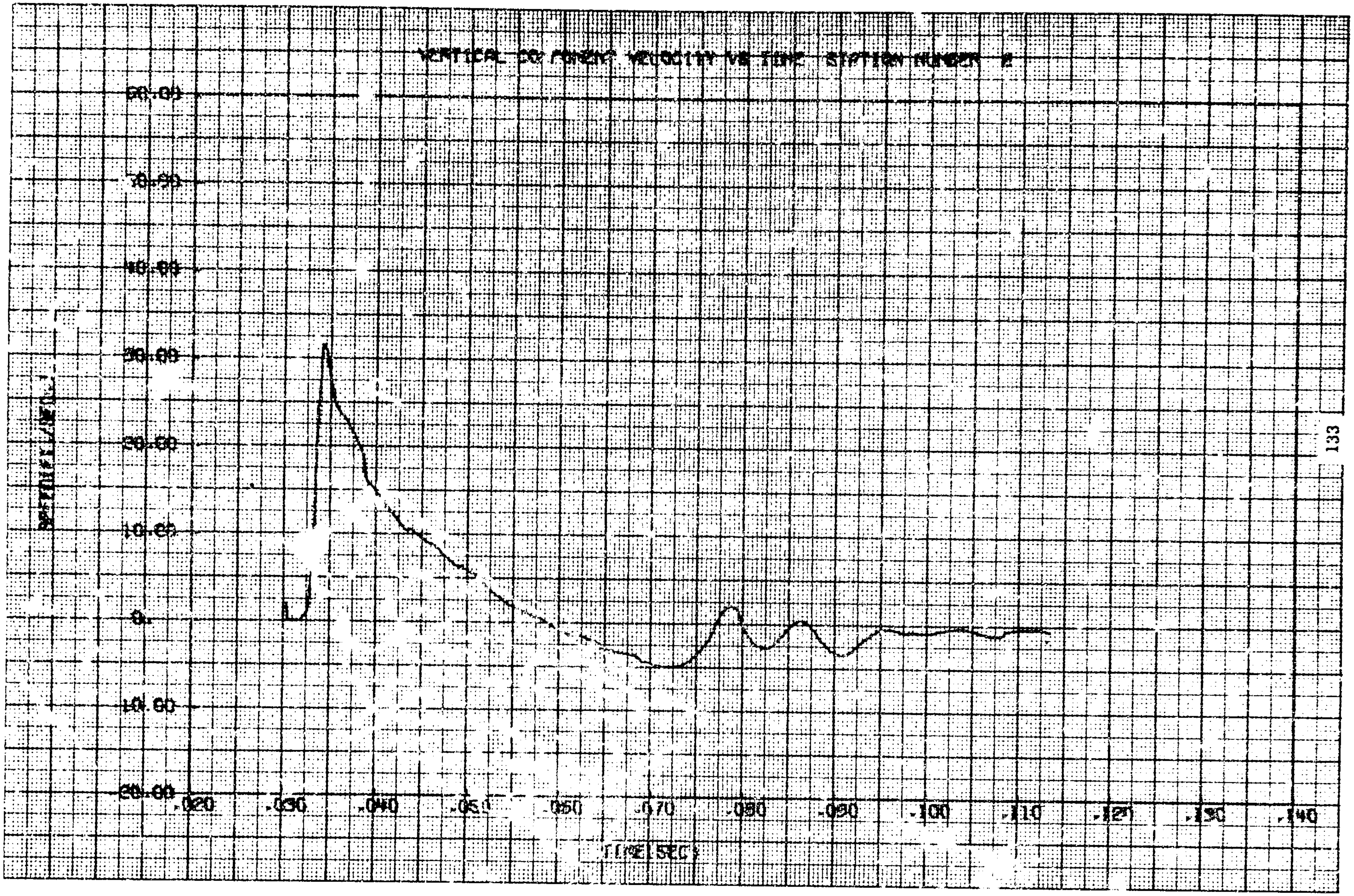
VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 7
DYNAMIC PRESSURE IMPULSE
0
.010
.020
.030
.040
.050
.060
.070
.090
.100
.110
.120
.130
TIME (SEC)

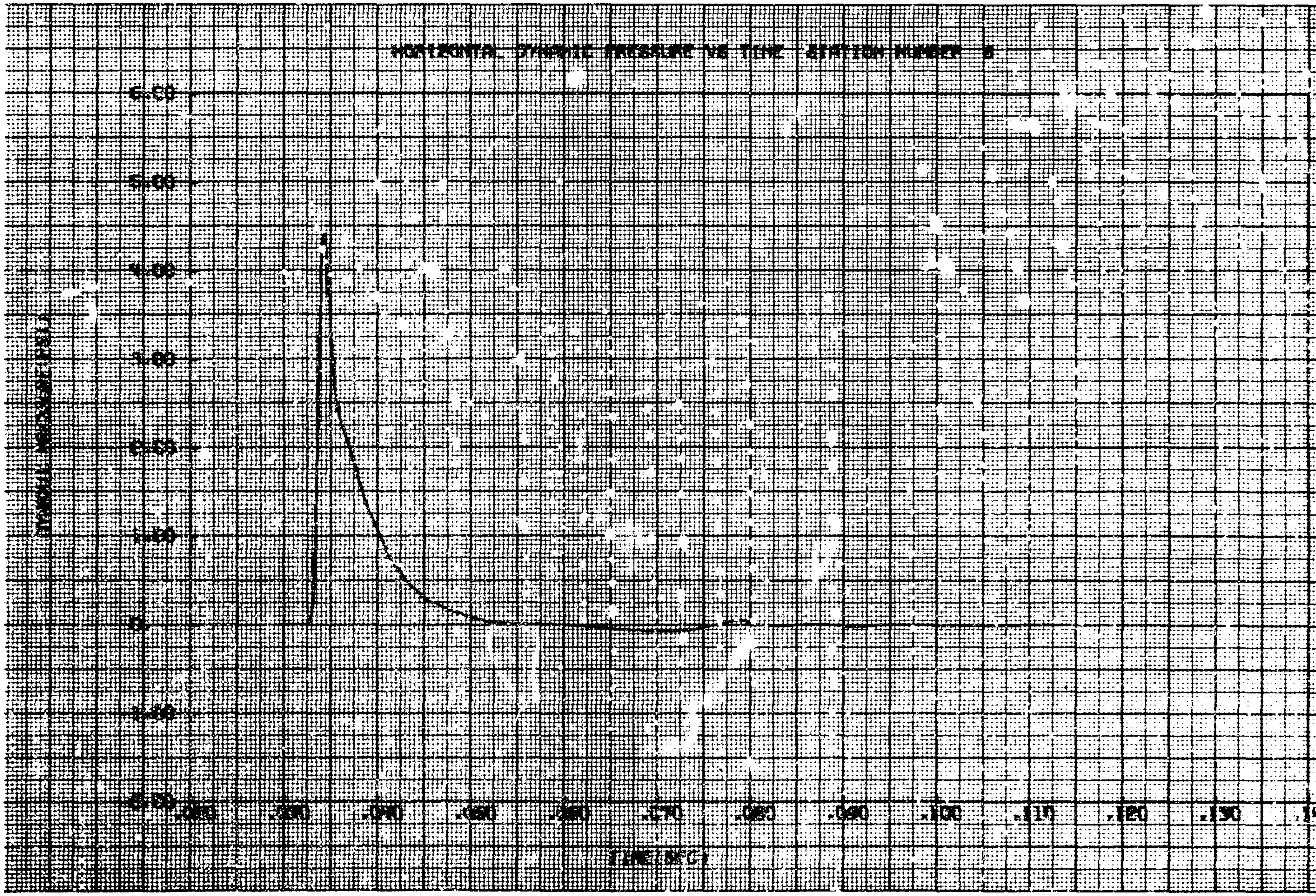

OVER PRESSURE VS TIME STATION NUMBER
OVER-PRESSURE(PSI)
24.00
20.00
16.00
12.00
8.00
4.00
0.
-4.00
-8.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME(SEC)

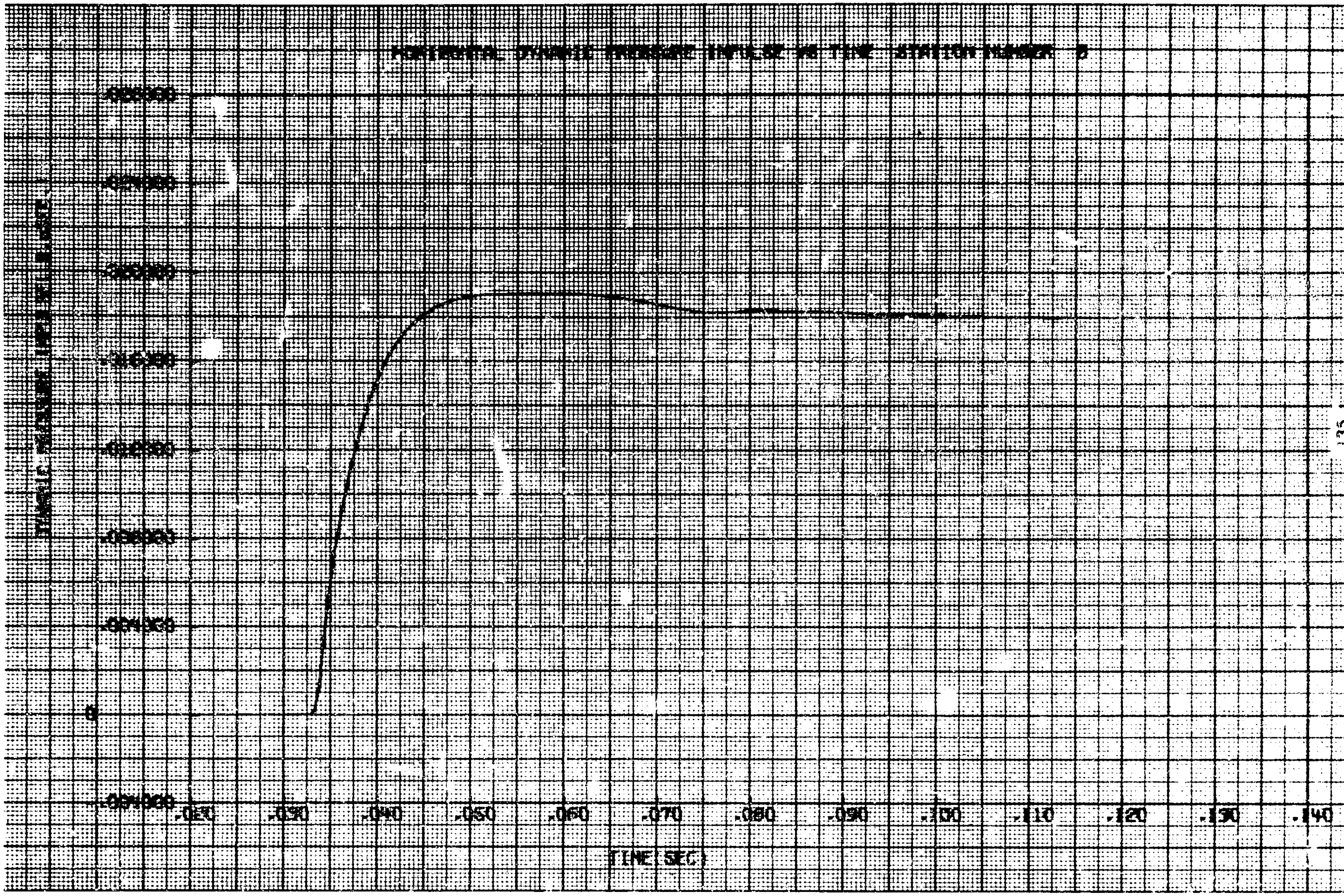


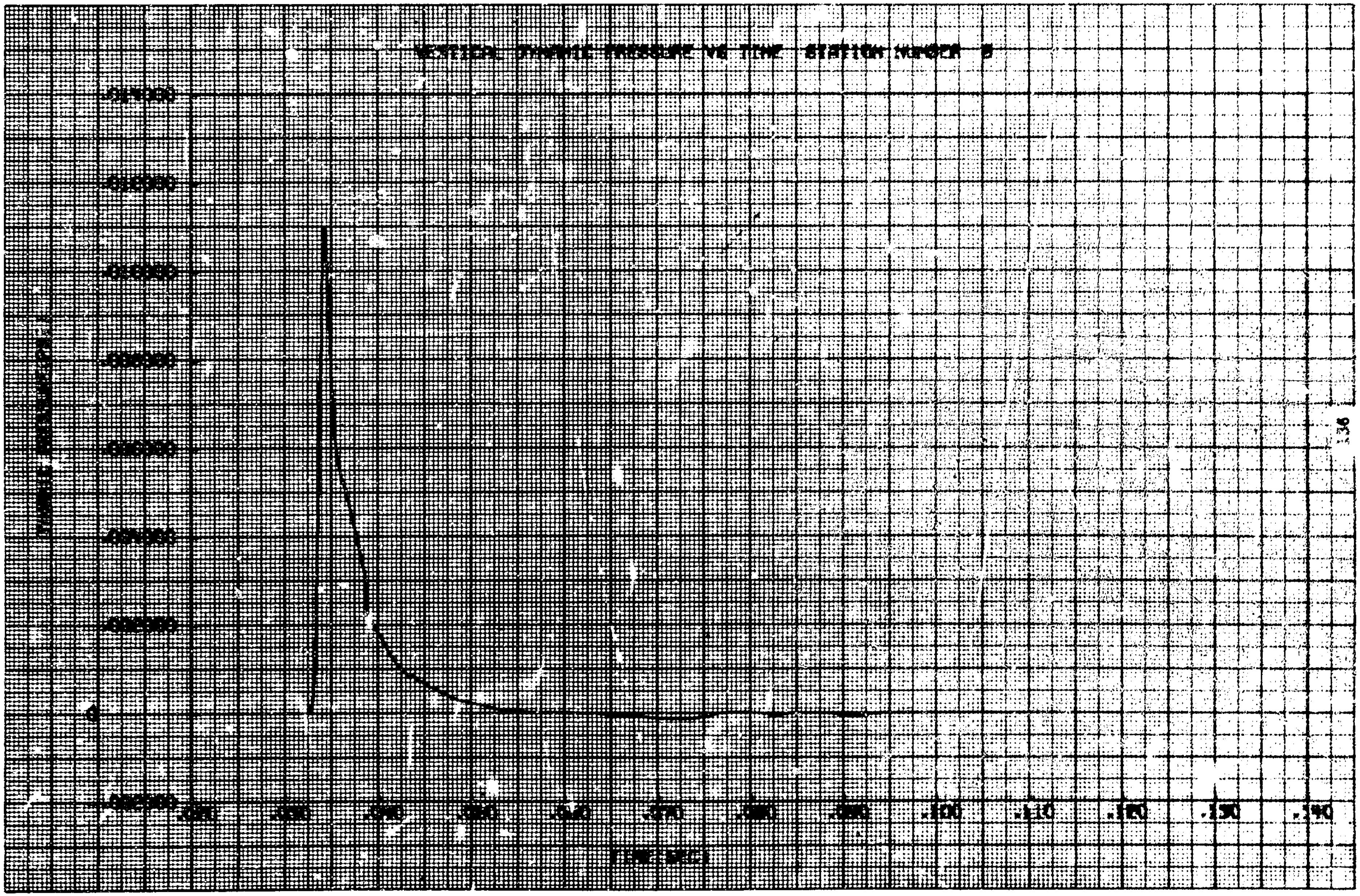
OVER PRESSURE IMPULSE VS TIME STATION NUMBER 8
OVER PRESSURE IMPULSE(LB.-SEC.)
.14
.12
.10
.08
.06
.04
.02
0
-.02
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME (SEC)

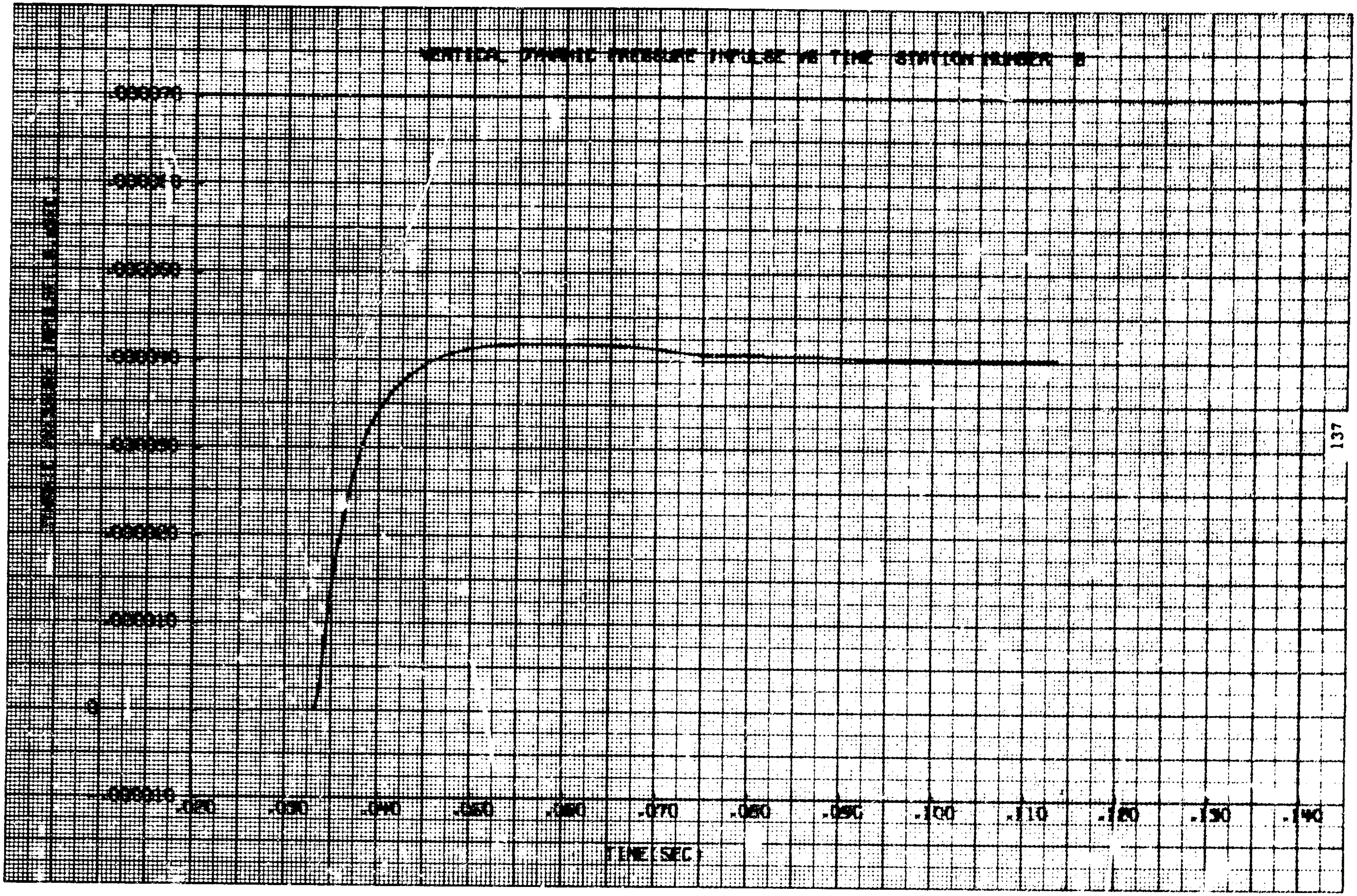

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER
1200.00
1000.00
800.00
600.00
400.00
200.00
0.
-200.00
-400.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME (SEC)

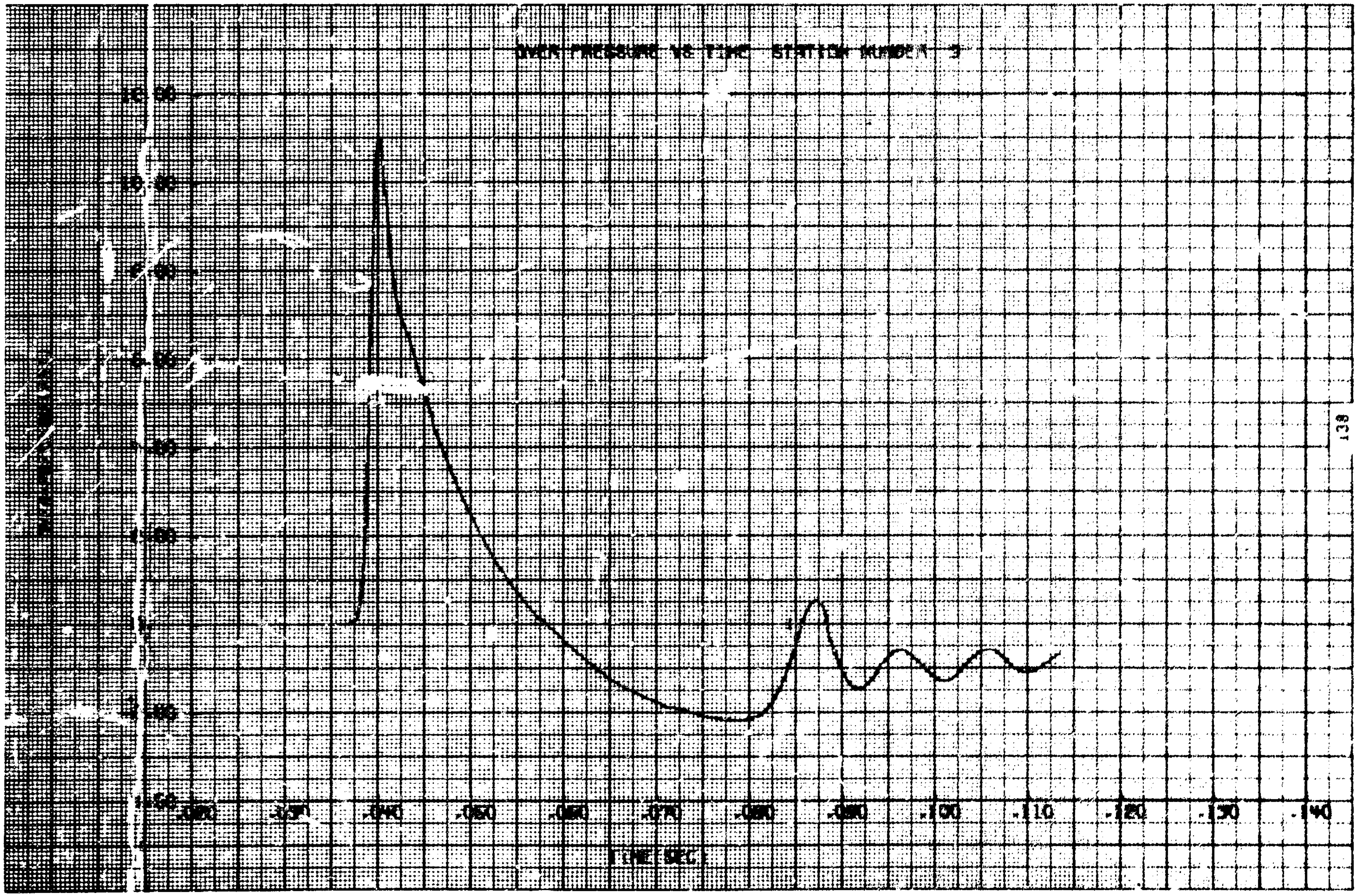

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER 2
VELOCITY(FT/SEC)
60.00
50.00
40.00
30.00
20.00
10.00
0.
-10.00
-20.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME(SEC)

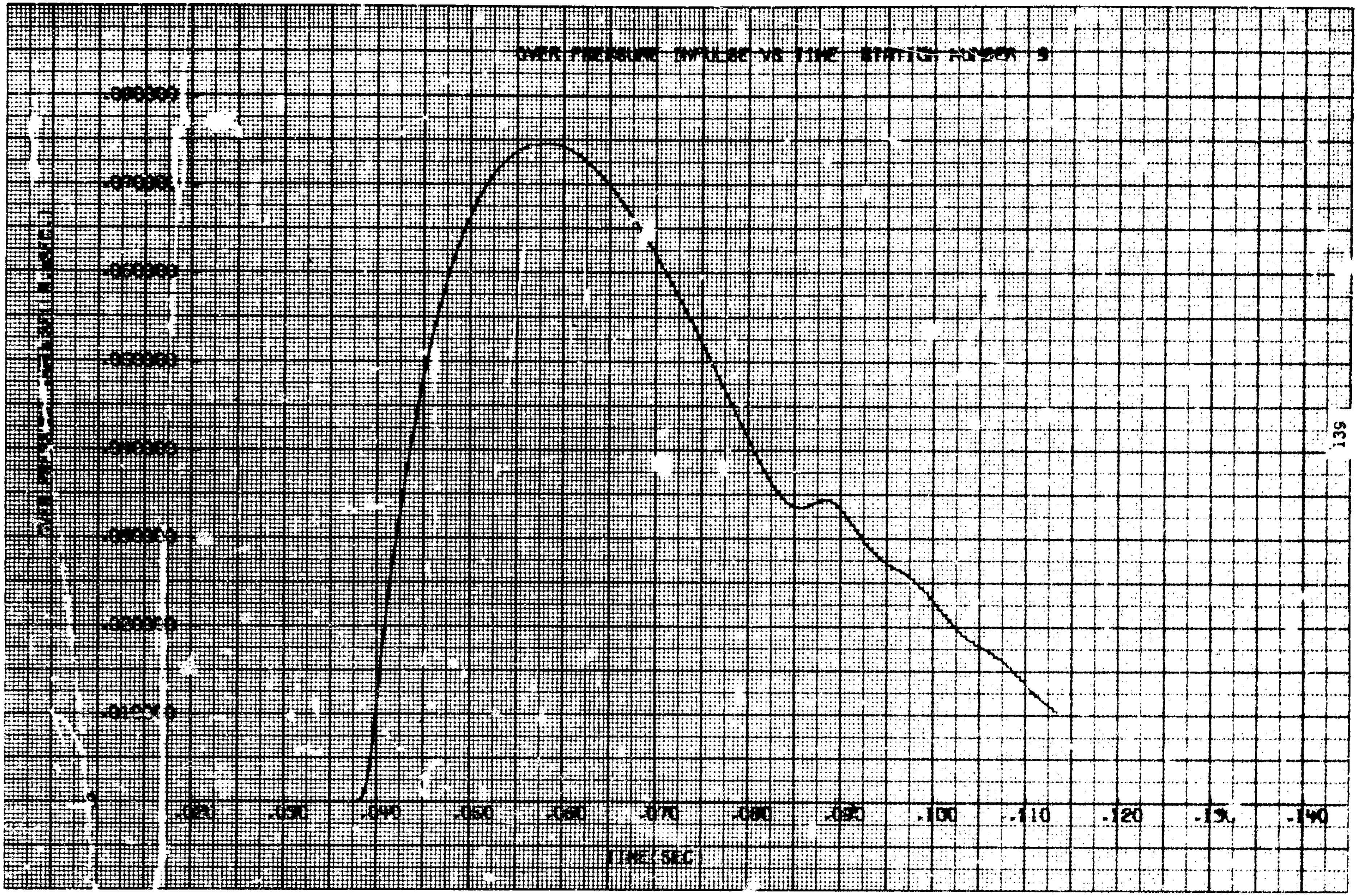

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 8
DYNAMIC PRESSURE (PSI)
6.00
5.00
4.00
3.00
2.00
1.00
0
-1.00
-2.00
.000
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME (SEC)

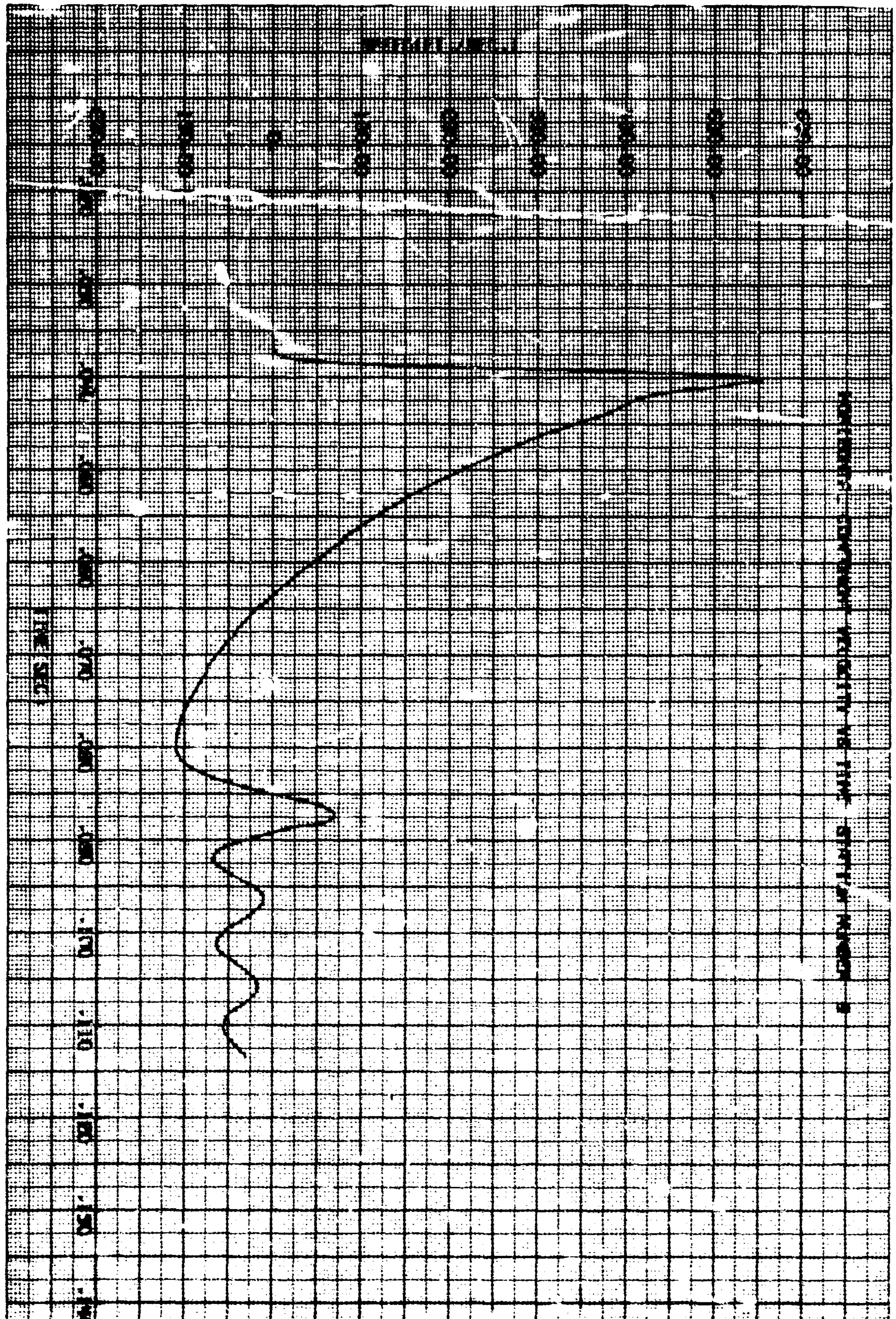

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER
0
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

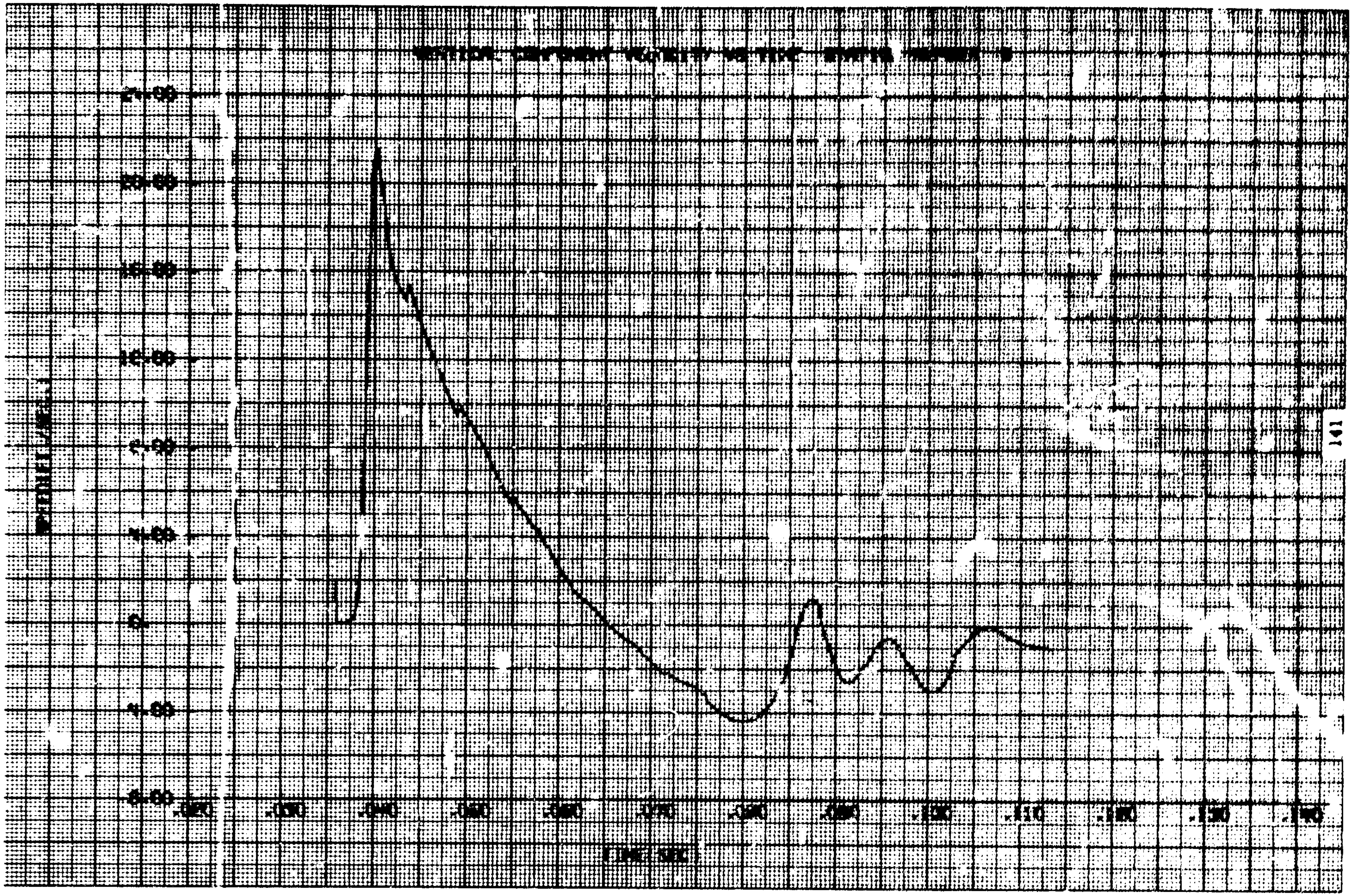

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER
0
.100
.110
.120
.130
.140

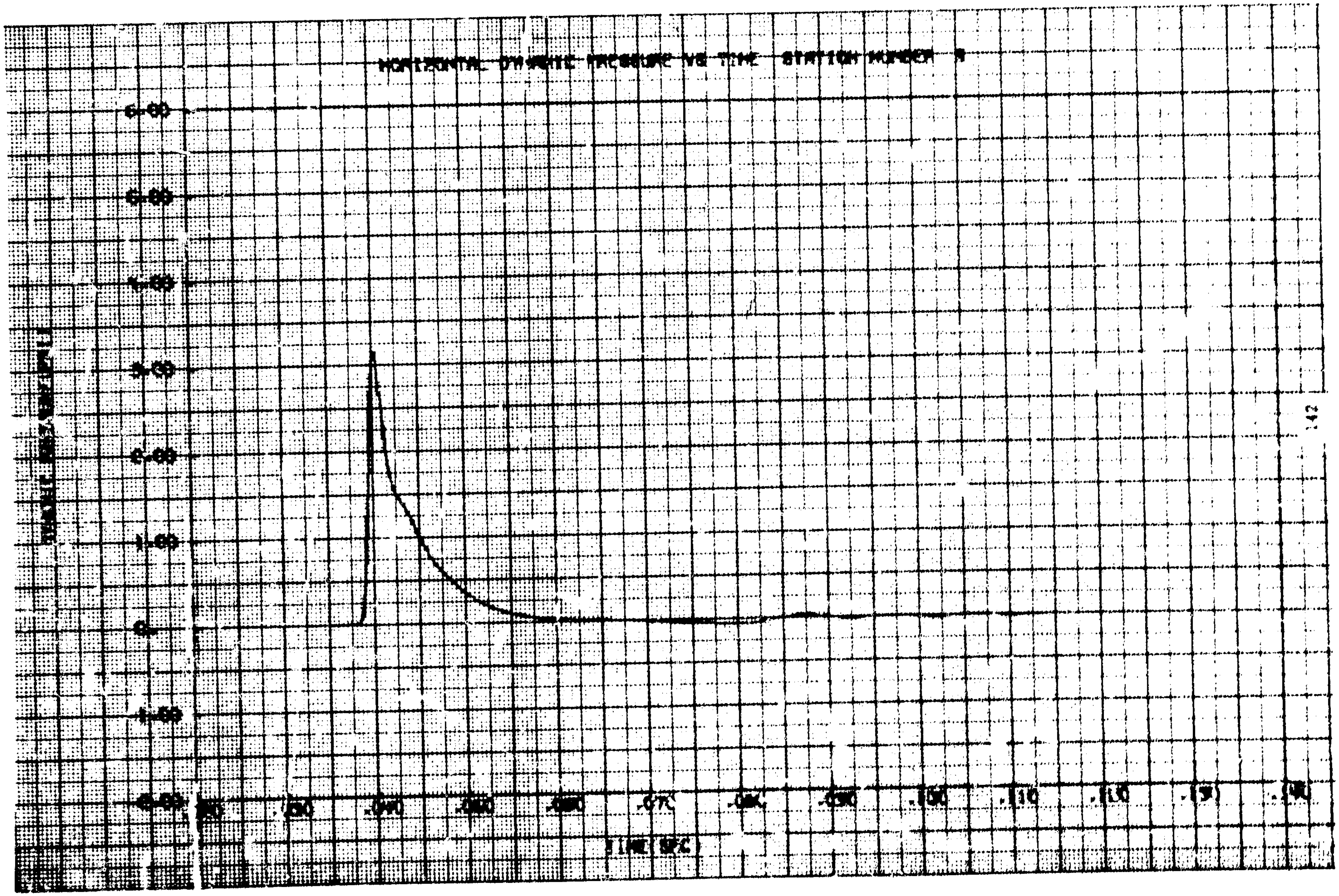

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 8
TIME (SEC)
.020
.030
.040
.070
.080
.100
.110
.140
0

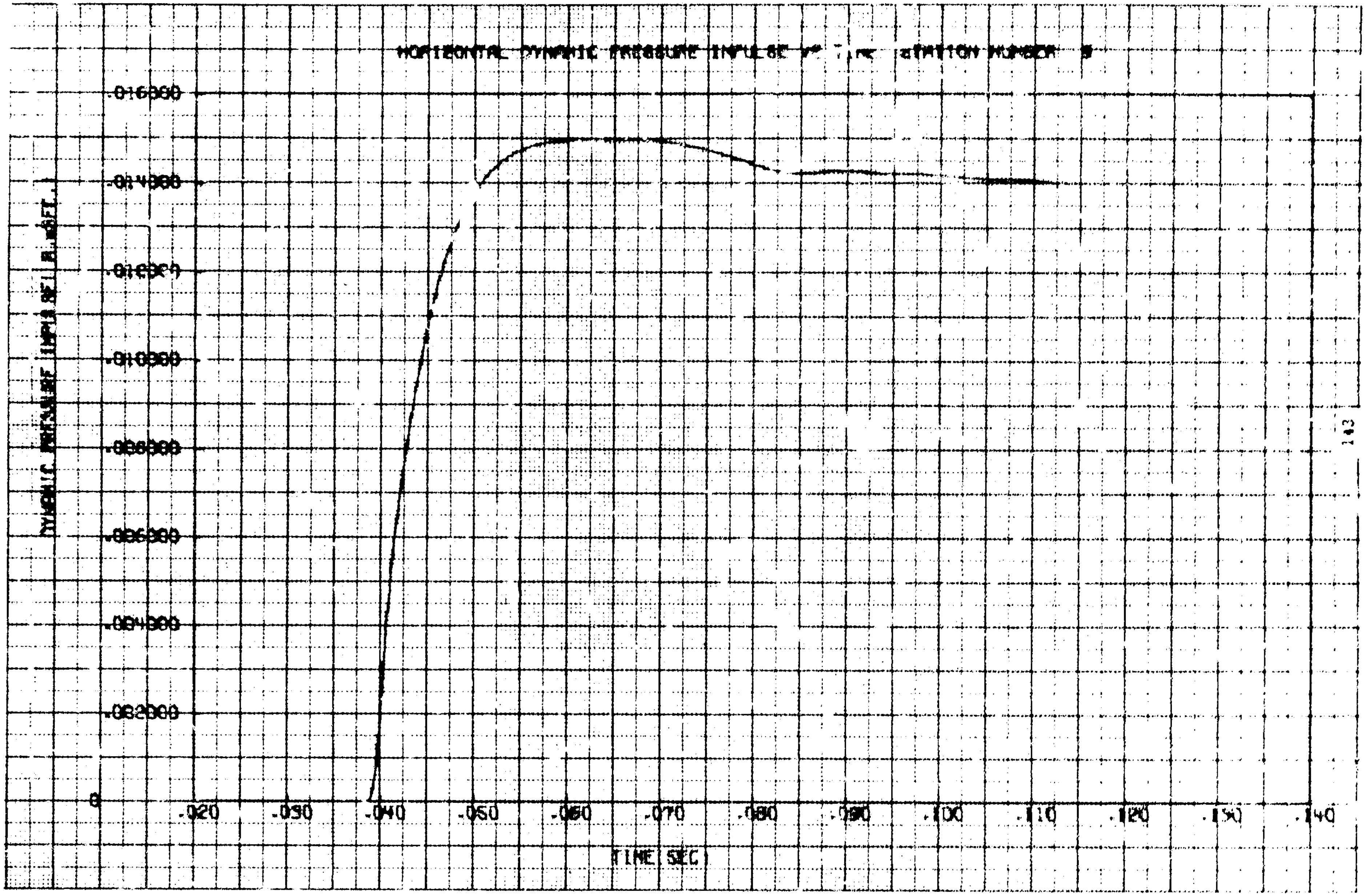

OVER PRESSURE VS TIME STATION NUMBER 3
.100
.110
.120
.130
.140
TIME SEC

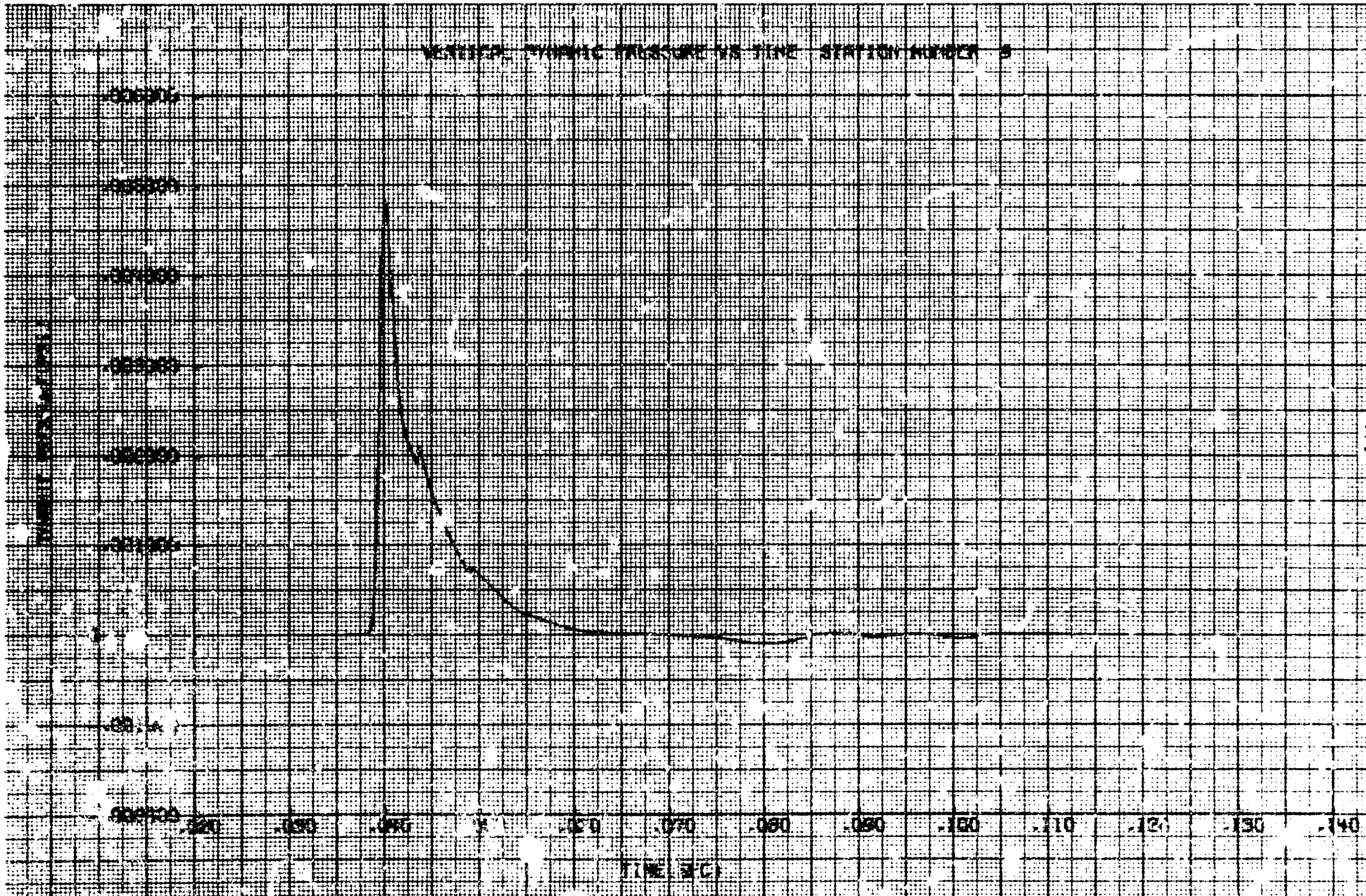

.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.140
TIME SEC

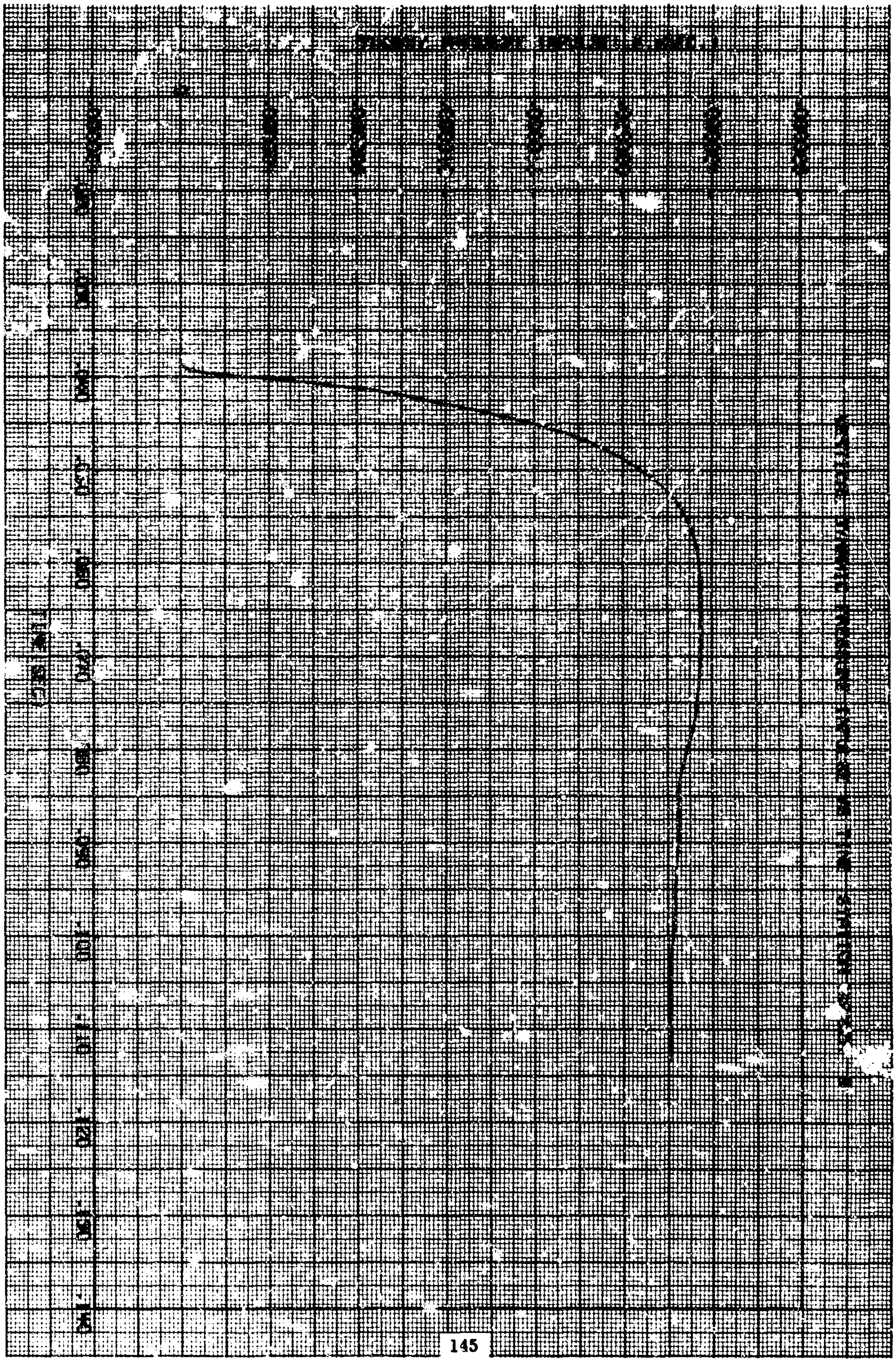


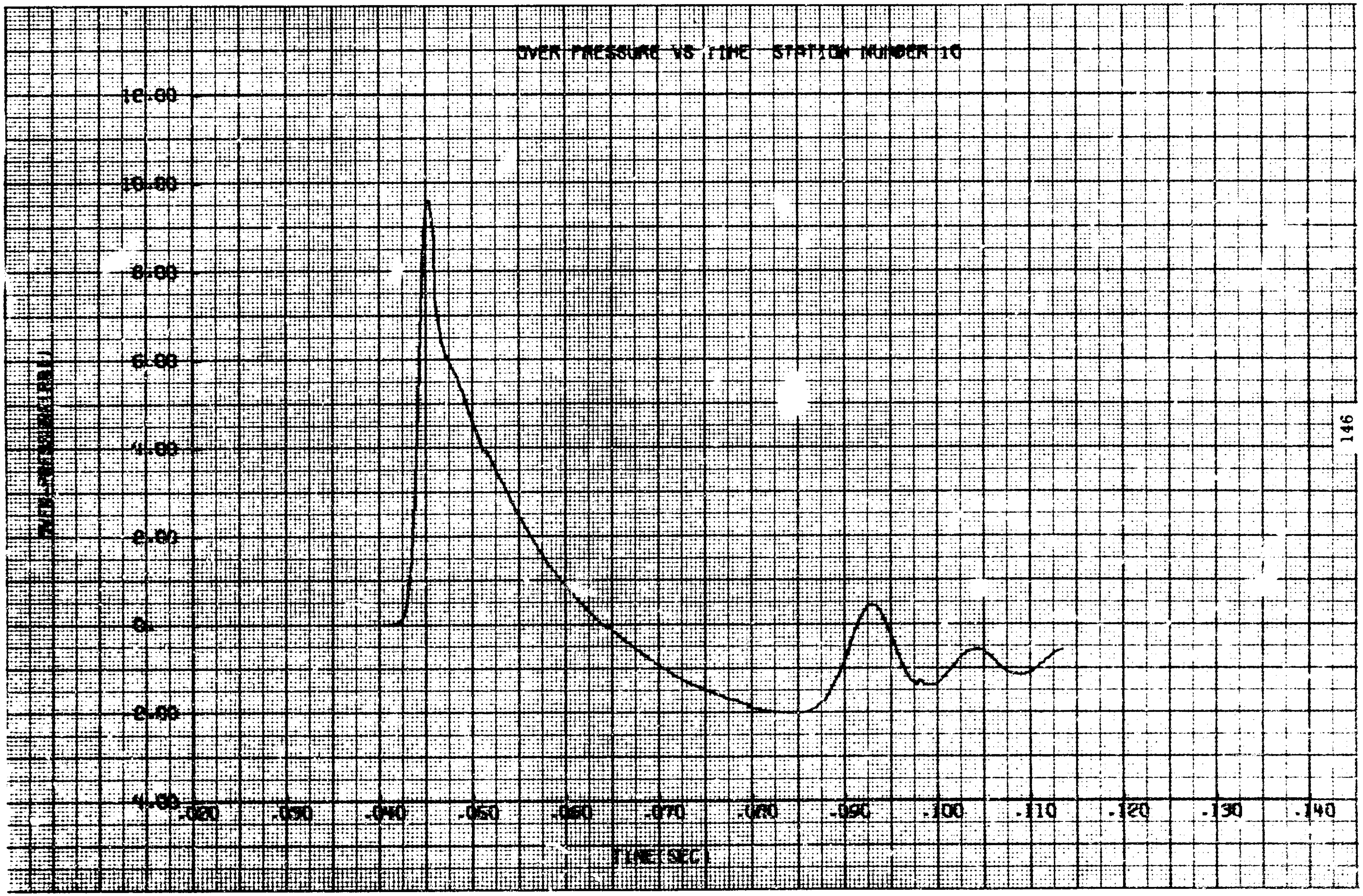

24.00
20.00
16.00
12.00
8.00
4.00
0.
-4.00
-8.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140

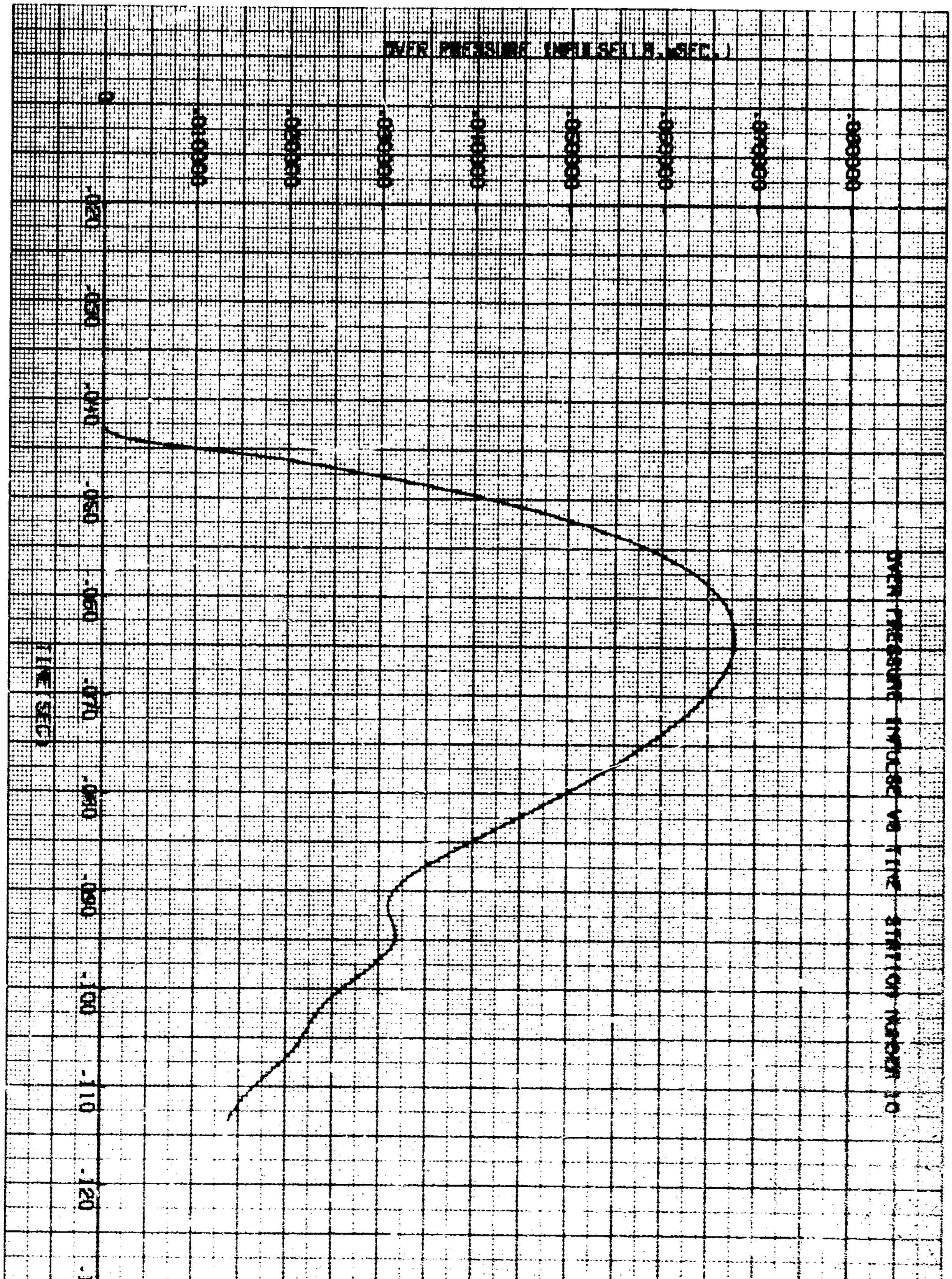

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER
6.00
5.00
4.00
3.00
2.00
1.00
0.
-1.00
-2.00
TIME (SEC)

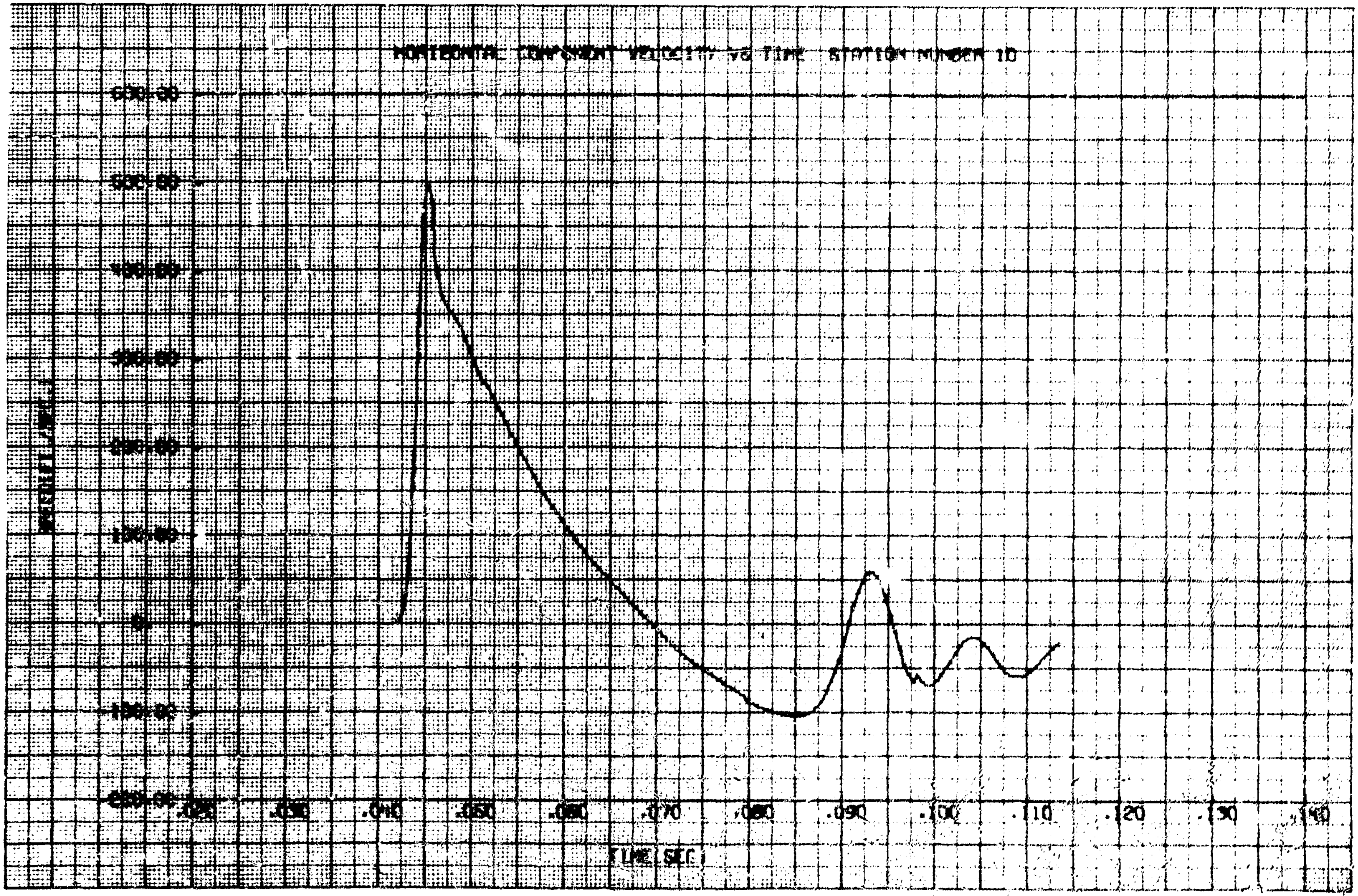

HORIZONTAL DYNAMIC PRESSURE IMPULSE
.016000
.014000
.012000
.010000
.008000
.006000
.004000
.002000
0
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

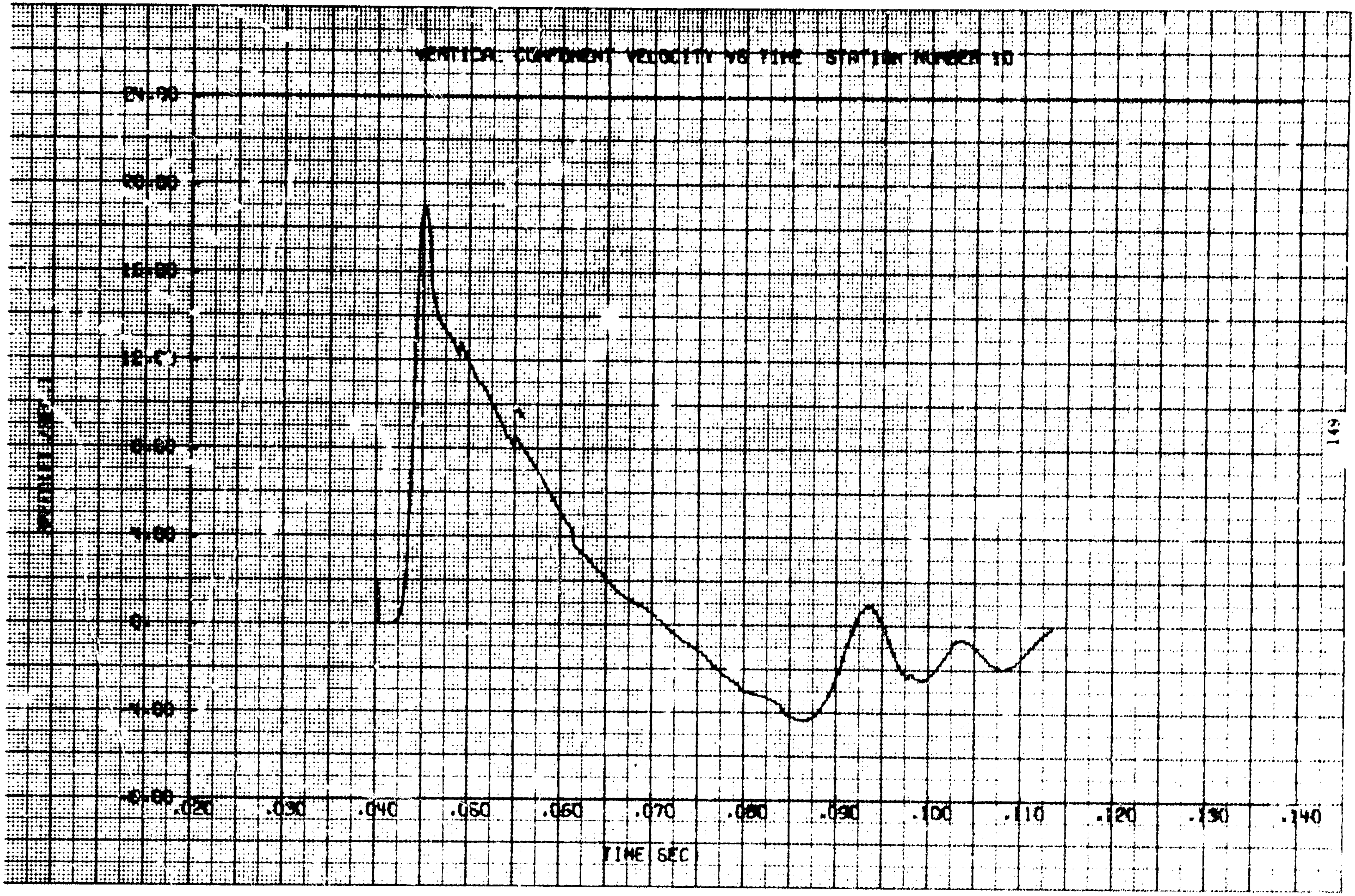

.030
.040
.070
.080
.090
.100
.110
.130
.140
TIME SEC

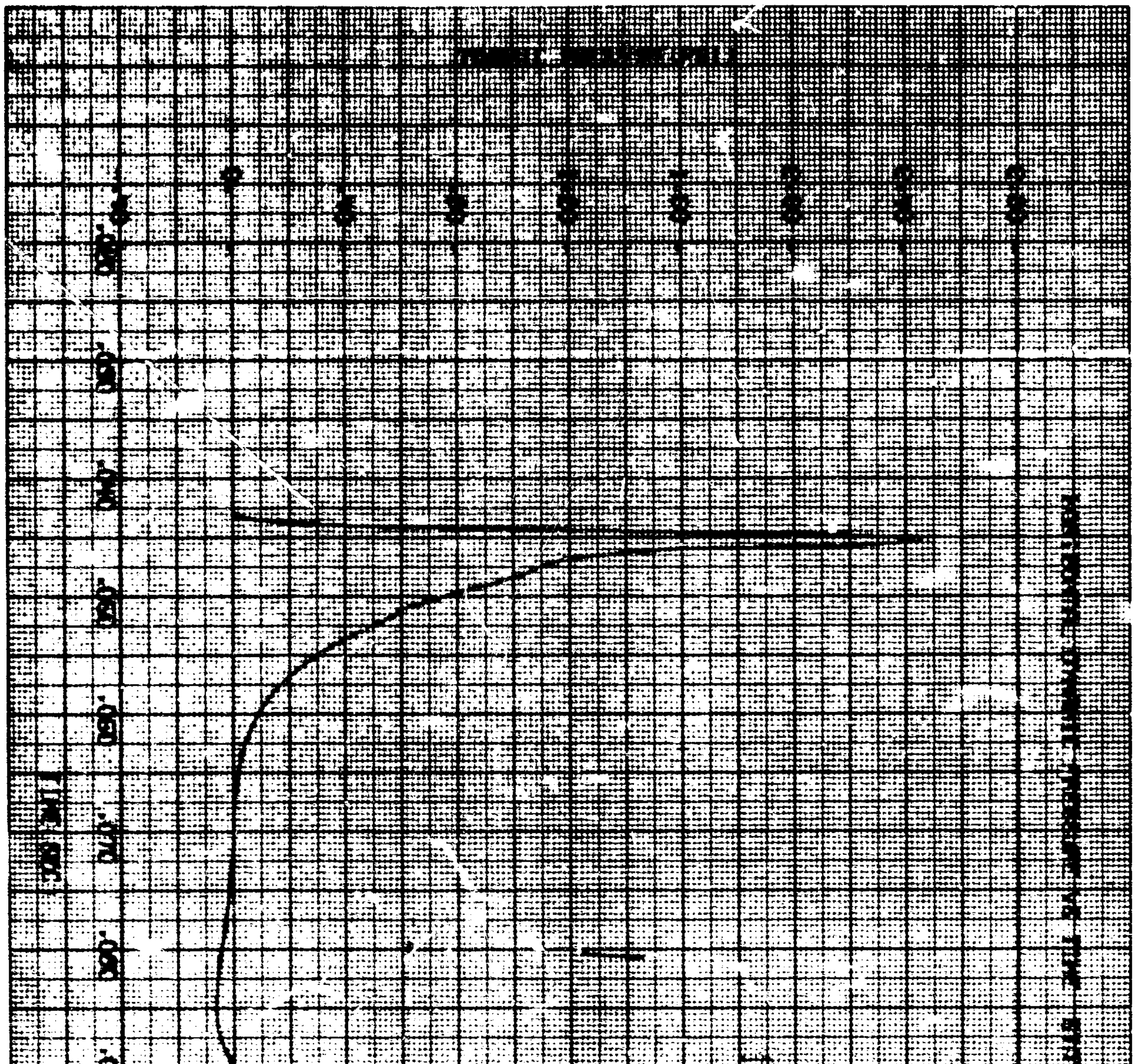


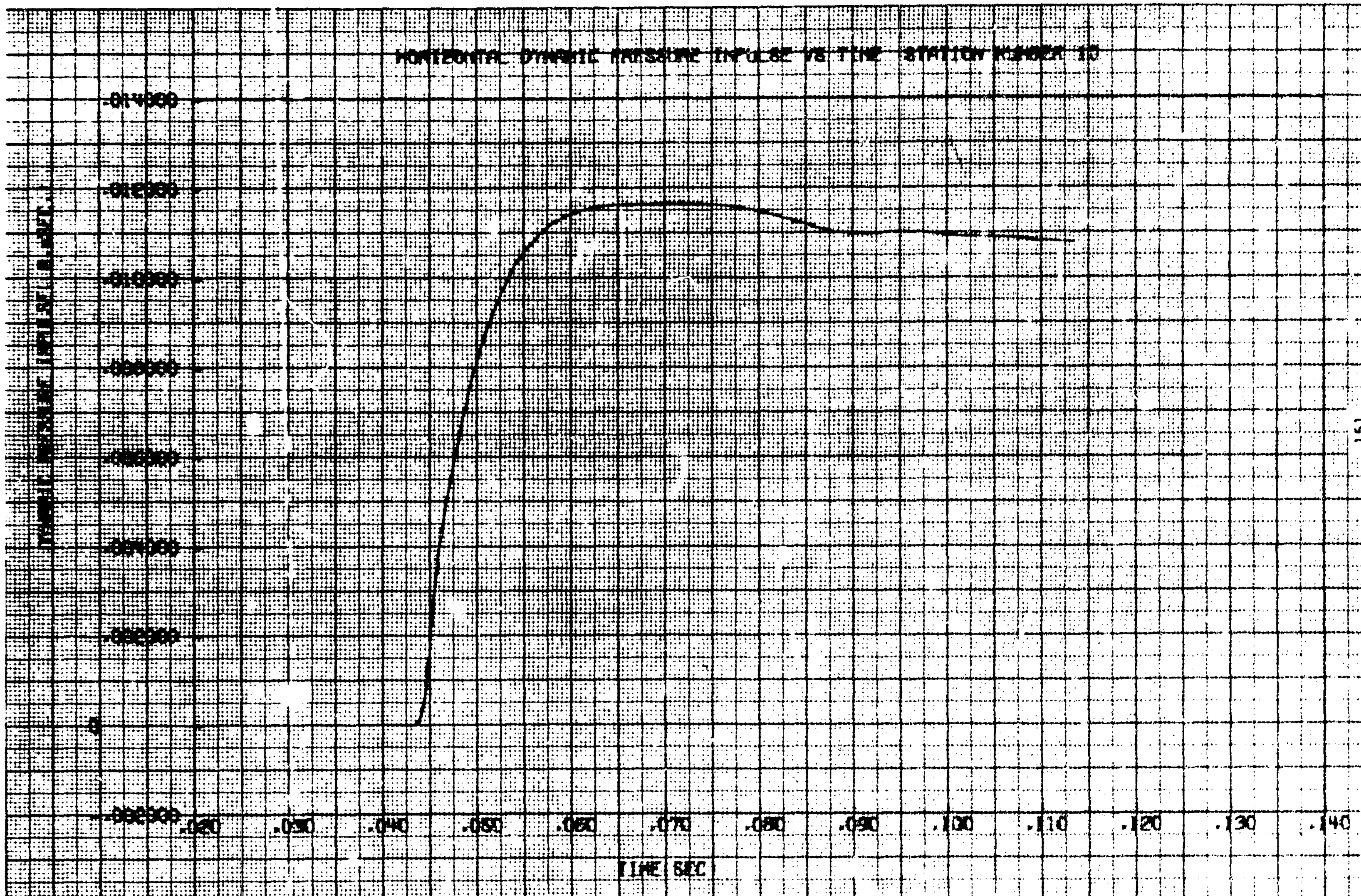

OVER PRESSURE VS TIME STATION NUMBER 10
OVER-PRESSURE(PSI)
12.00
10.00
8.00
6.00
4.00
2.00
0.
-2.00
-4.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME(SEC)

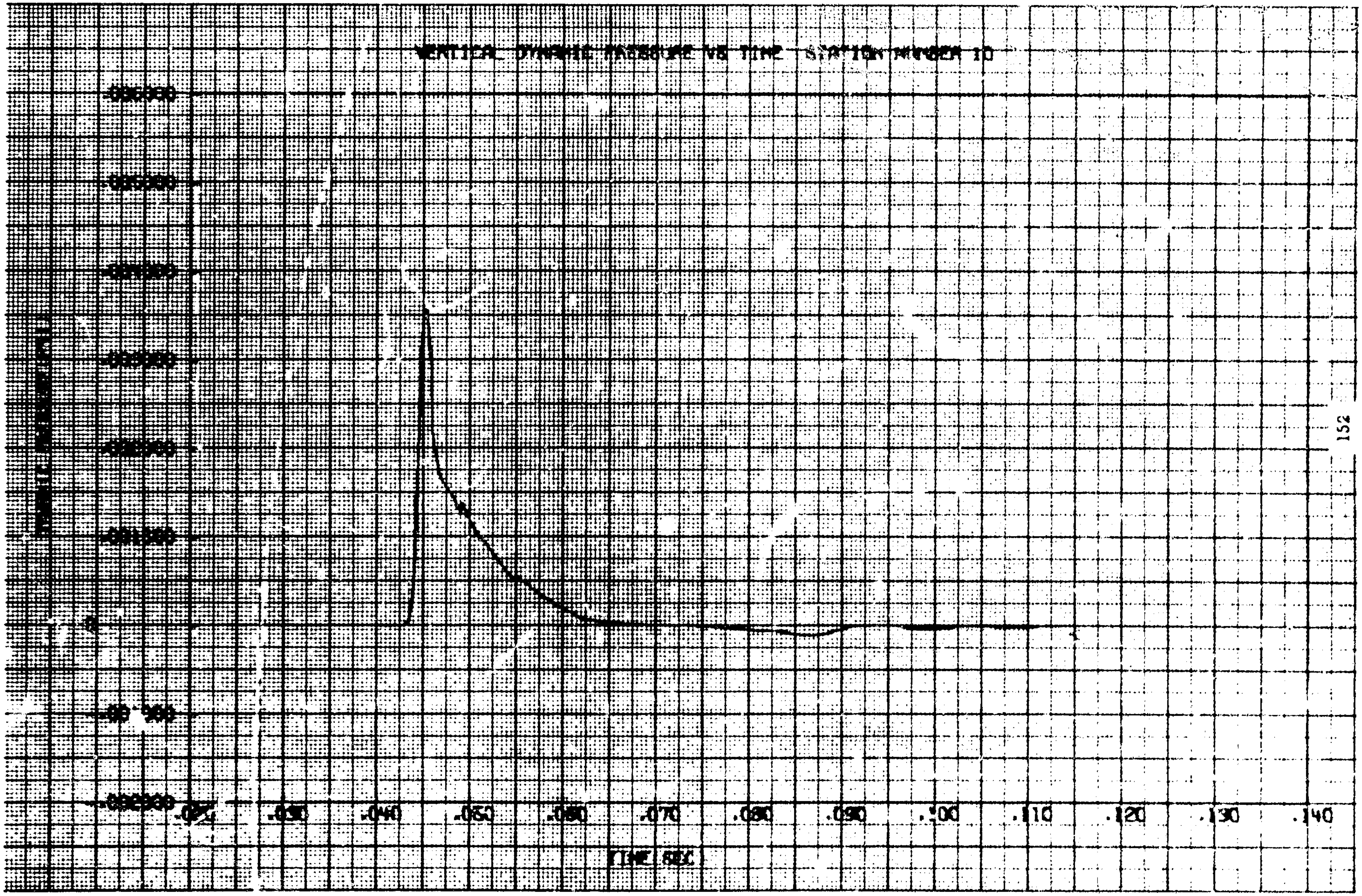

OVER PRESSURE IMPULSE VS TIME STATION NUMBER 10
TIME SEC

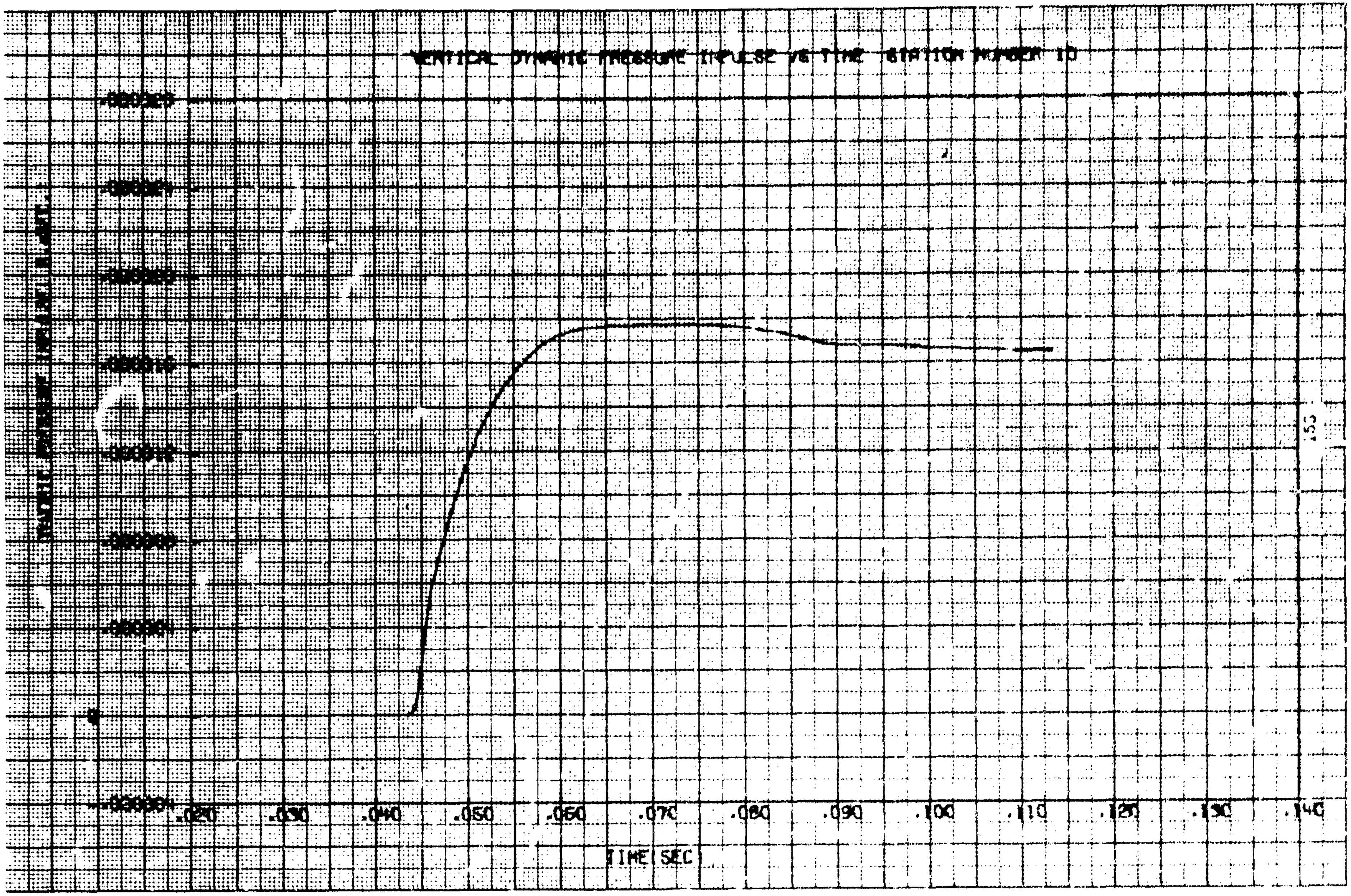

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 1D
600.00
500.00
400.00
300.00
200.00
100.00
0
-100.00
-200.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

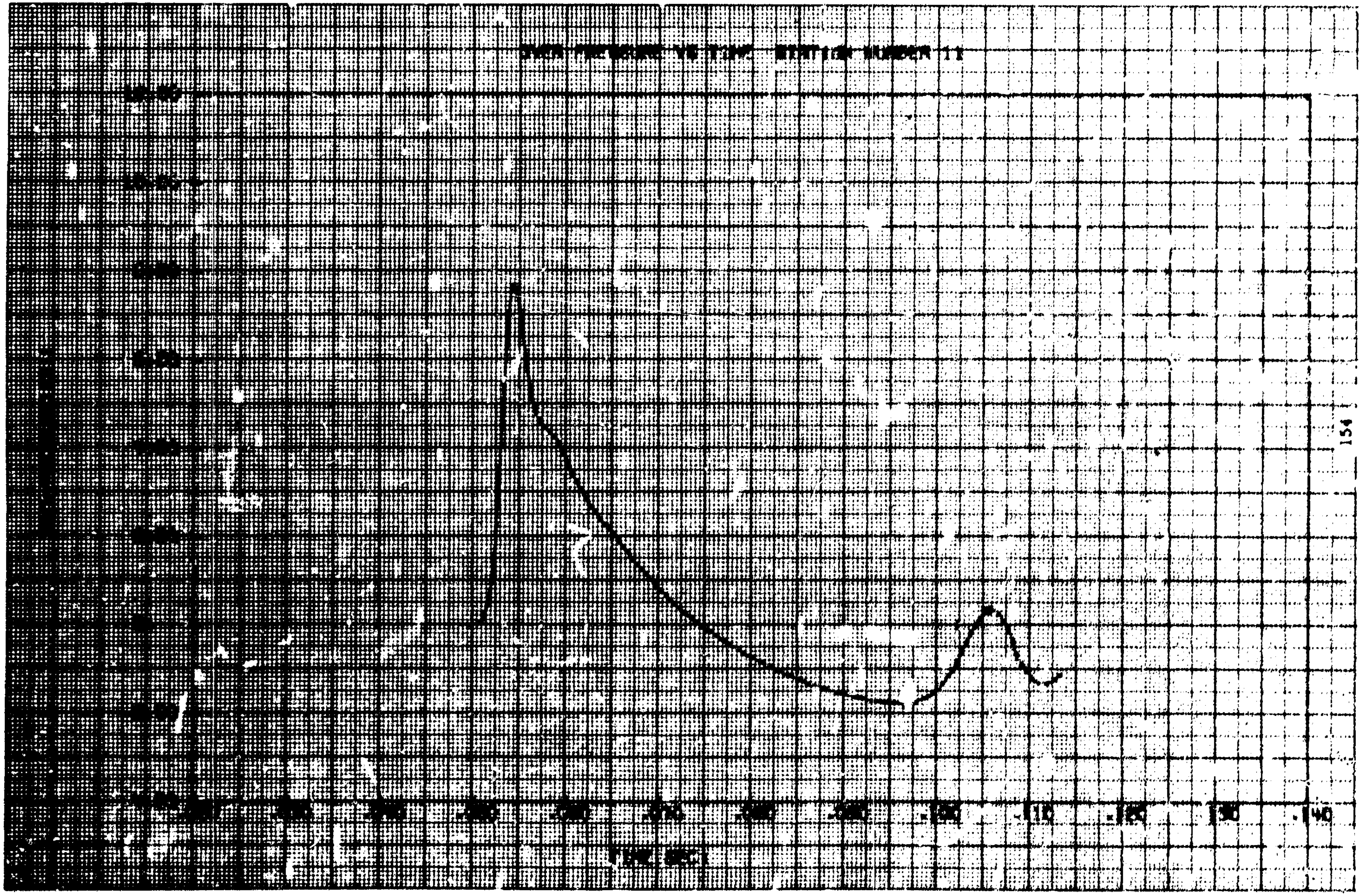

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER 10
24.00
20.00
16.00
12.00
8.00
4.00
0
-4.00
-8.00
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

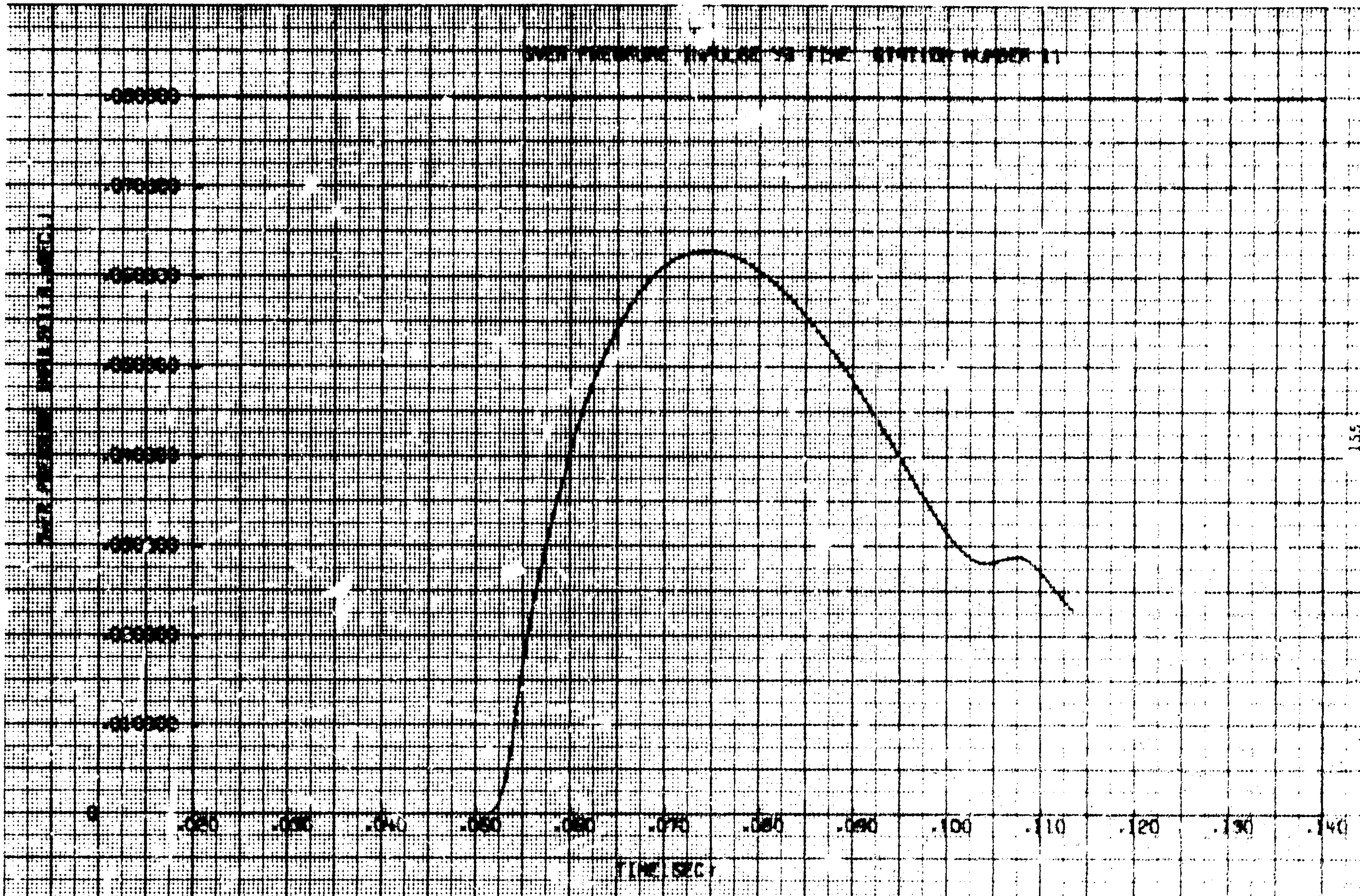


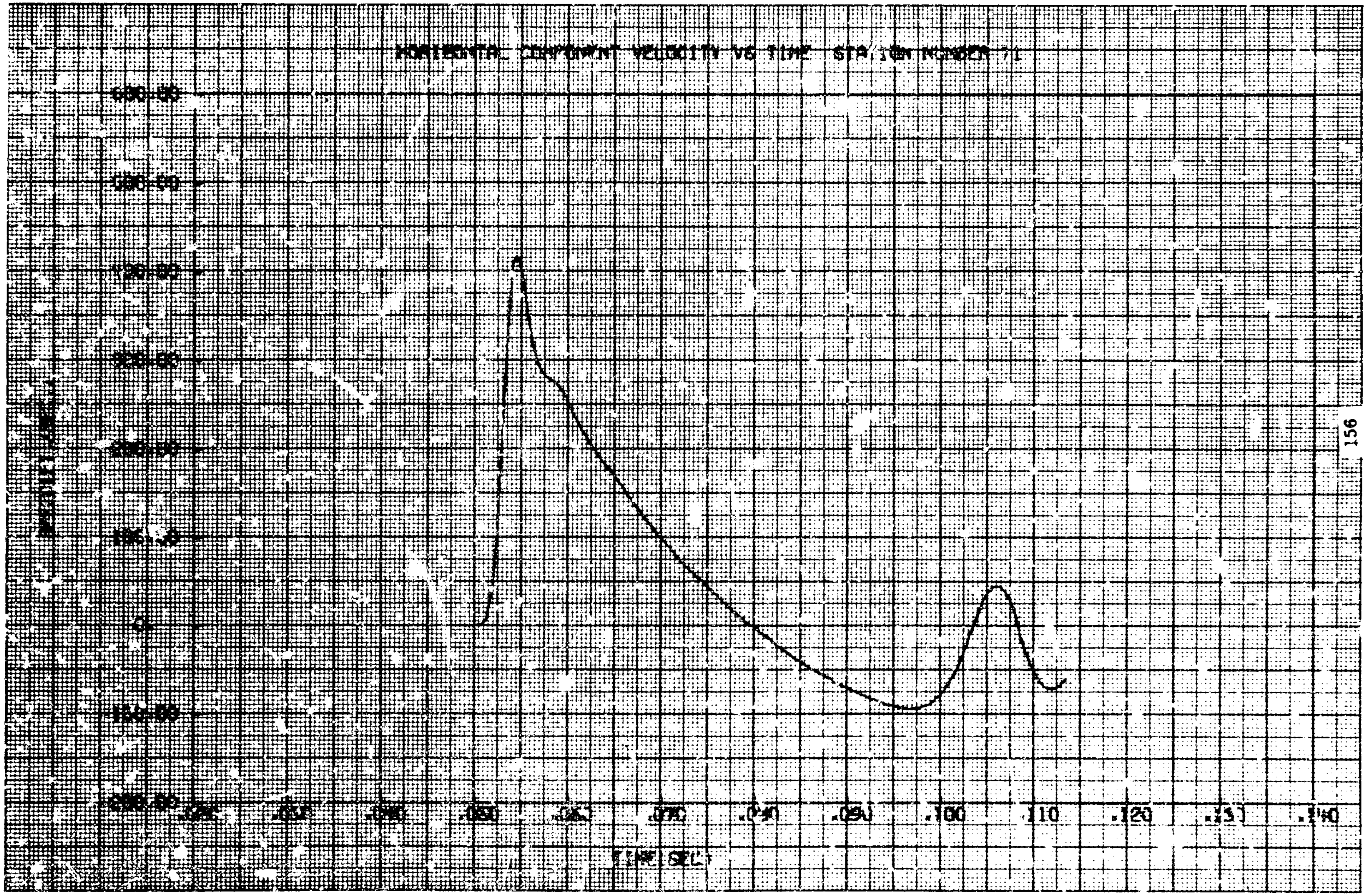

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 10
.014000
.012000
.010000
.008000
.006000
.004000
.002000
0
-.002000
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

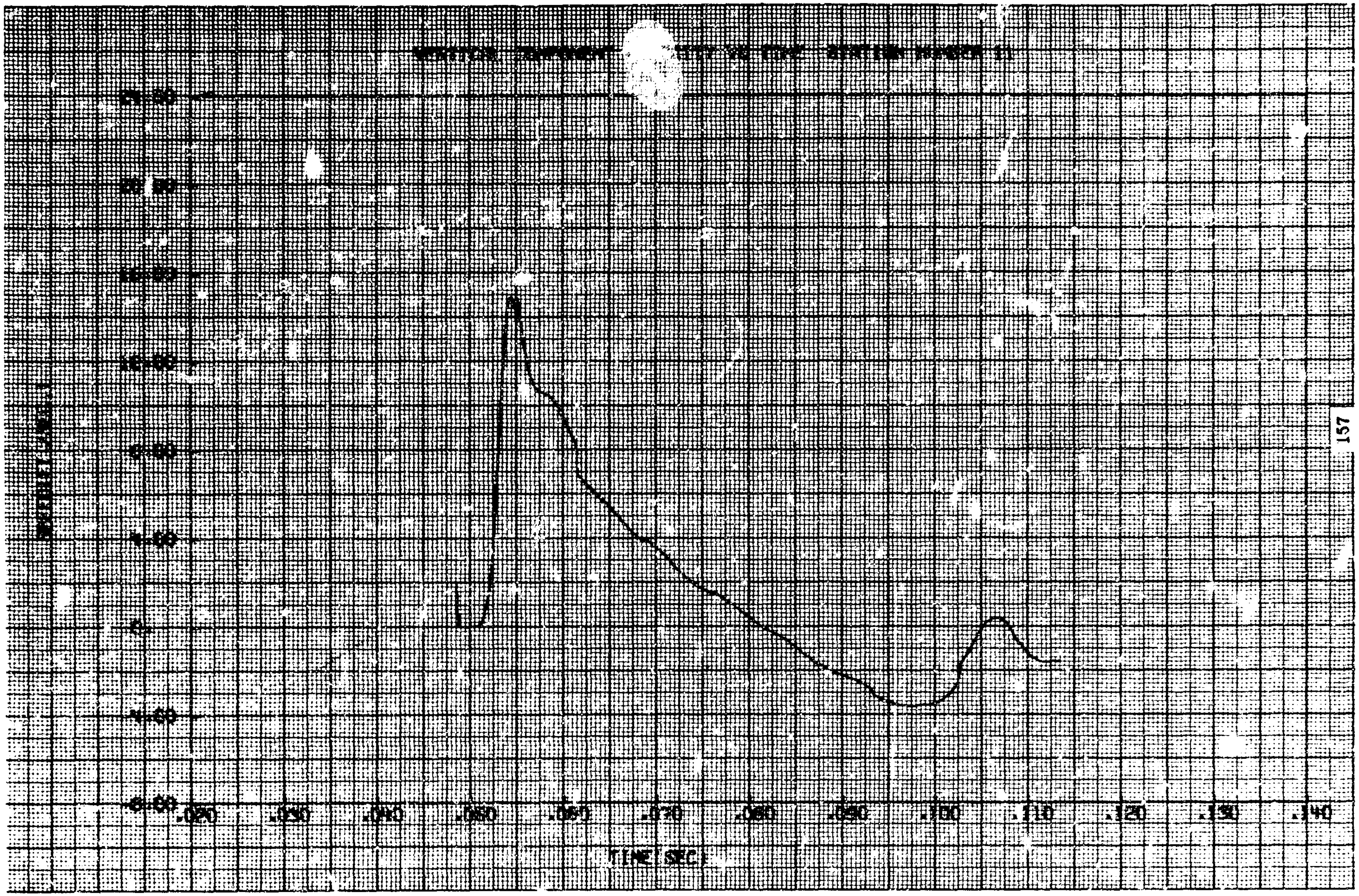

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 10
TIME SEC
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140

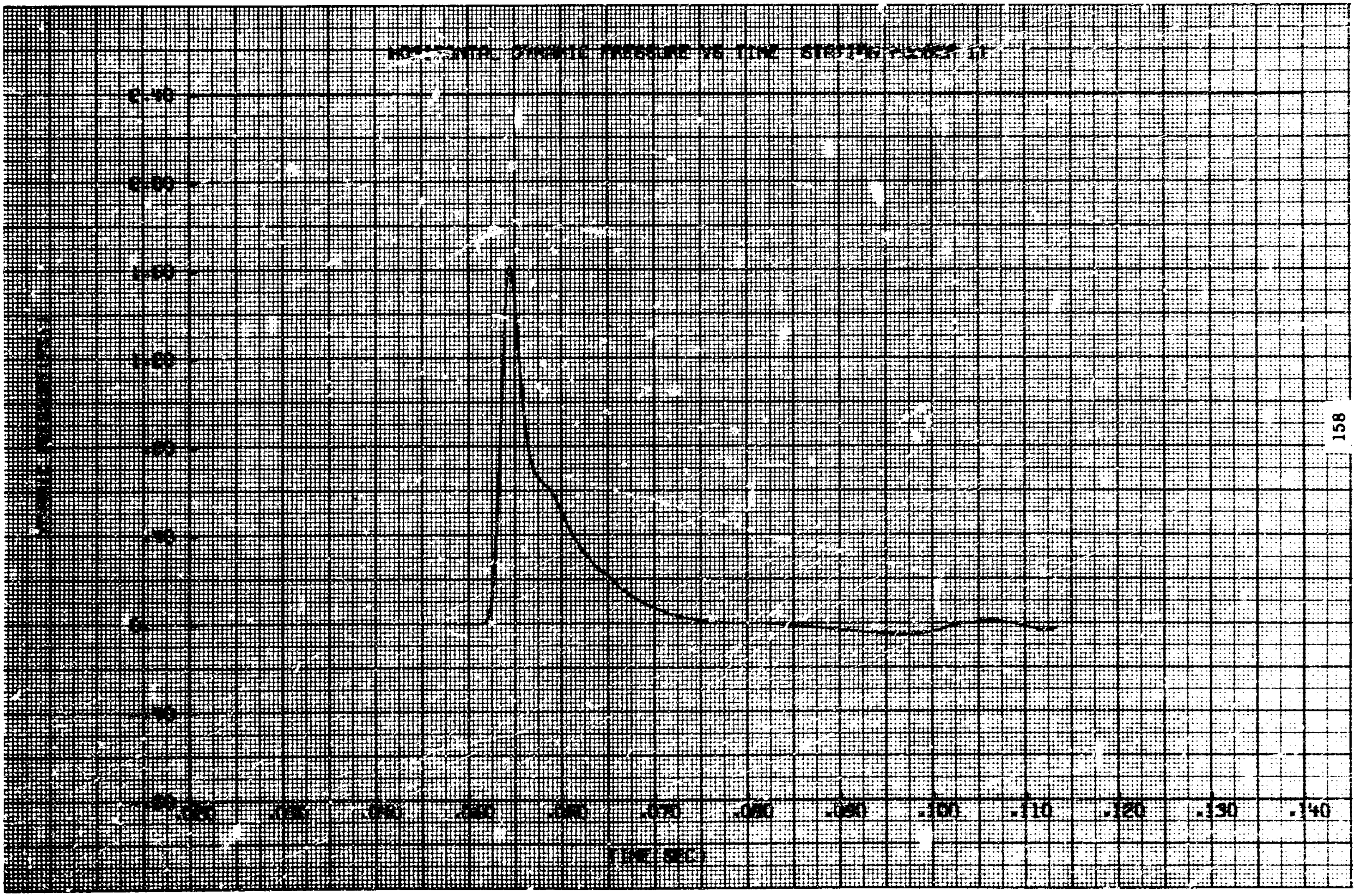

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 10
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC

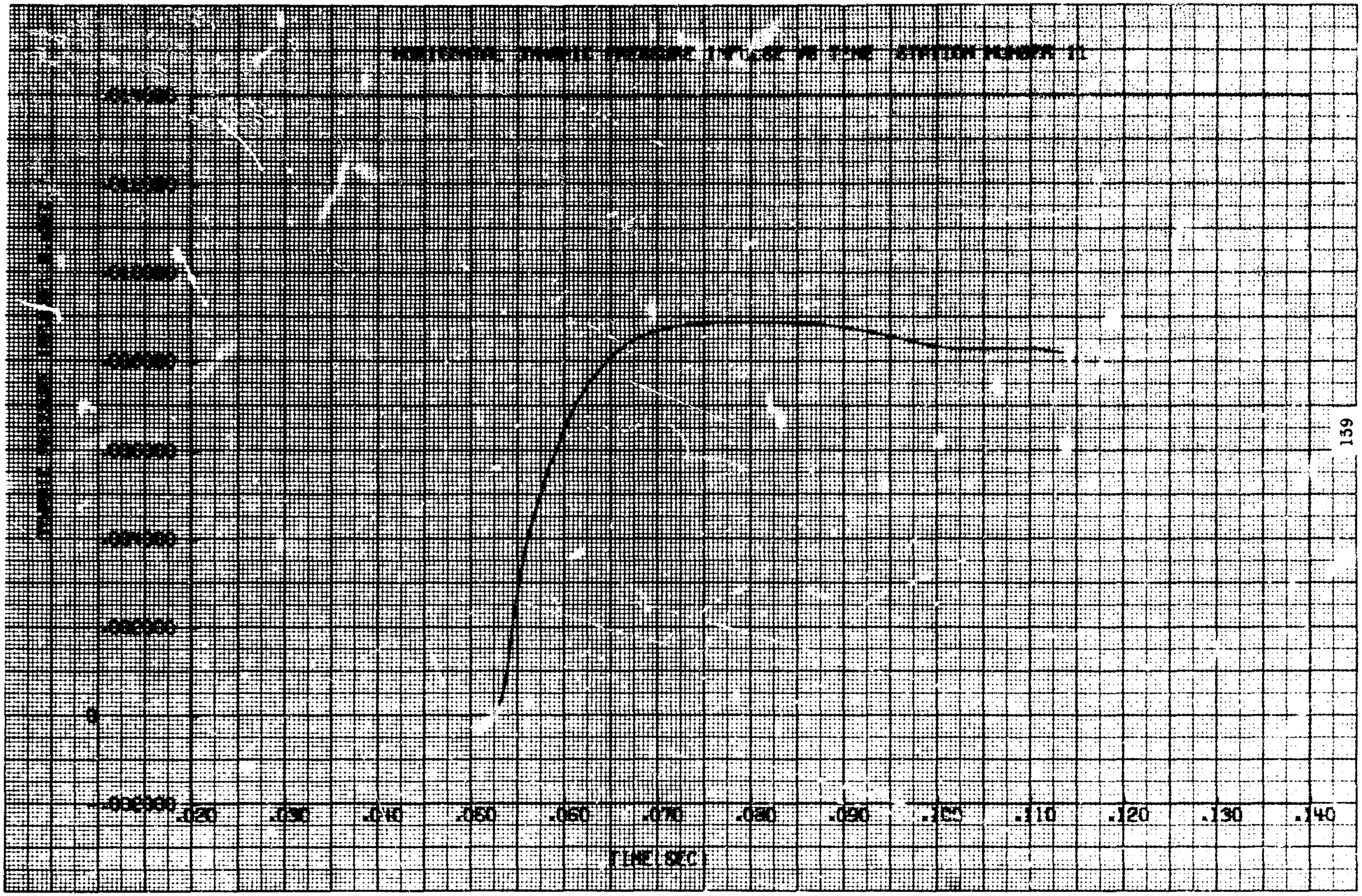

OVERPRESSURE VS TIME STATION NUMBER 11
TIME SEC


.100
.110
.120
.130
.140
TIME (SEC)

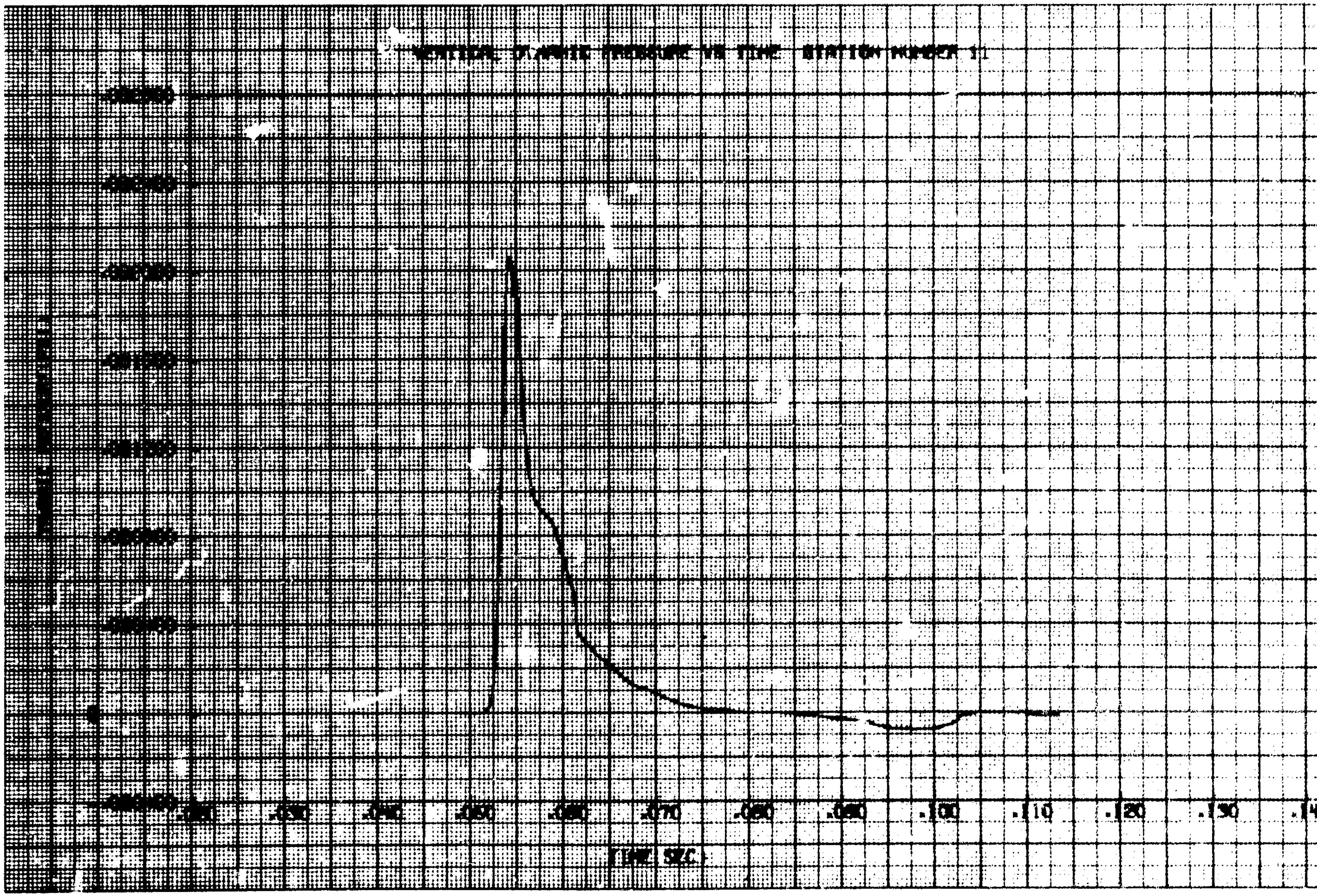

VS TIME
0
.050
.070
.090
.100
.110
.120
.140
TIME SEC

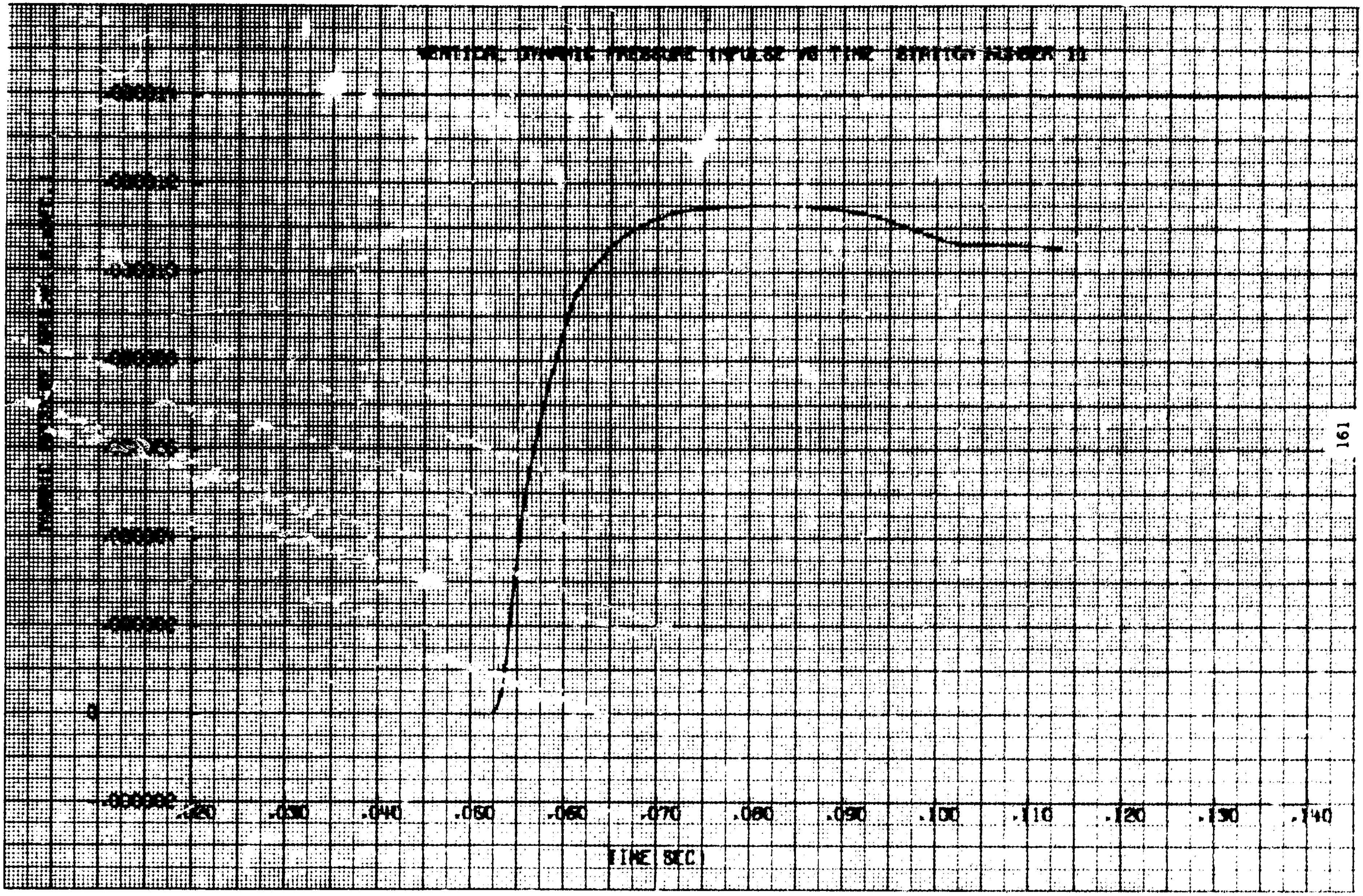

TIME (SEC)
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140


PRESSURE VS TIME
.110
.120
.130
.140
TIME SEC



0
.020
.030
.040
.050
.060
.070
.080
.090
.110
.120
.130
.140
TIME (SEC)

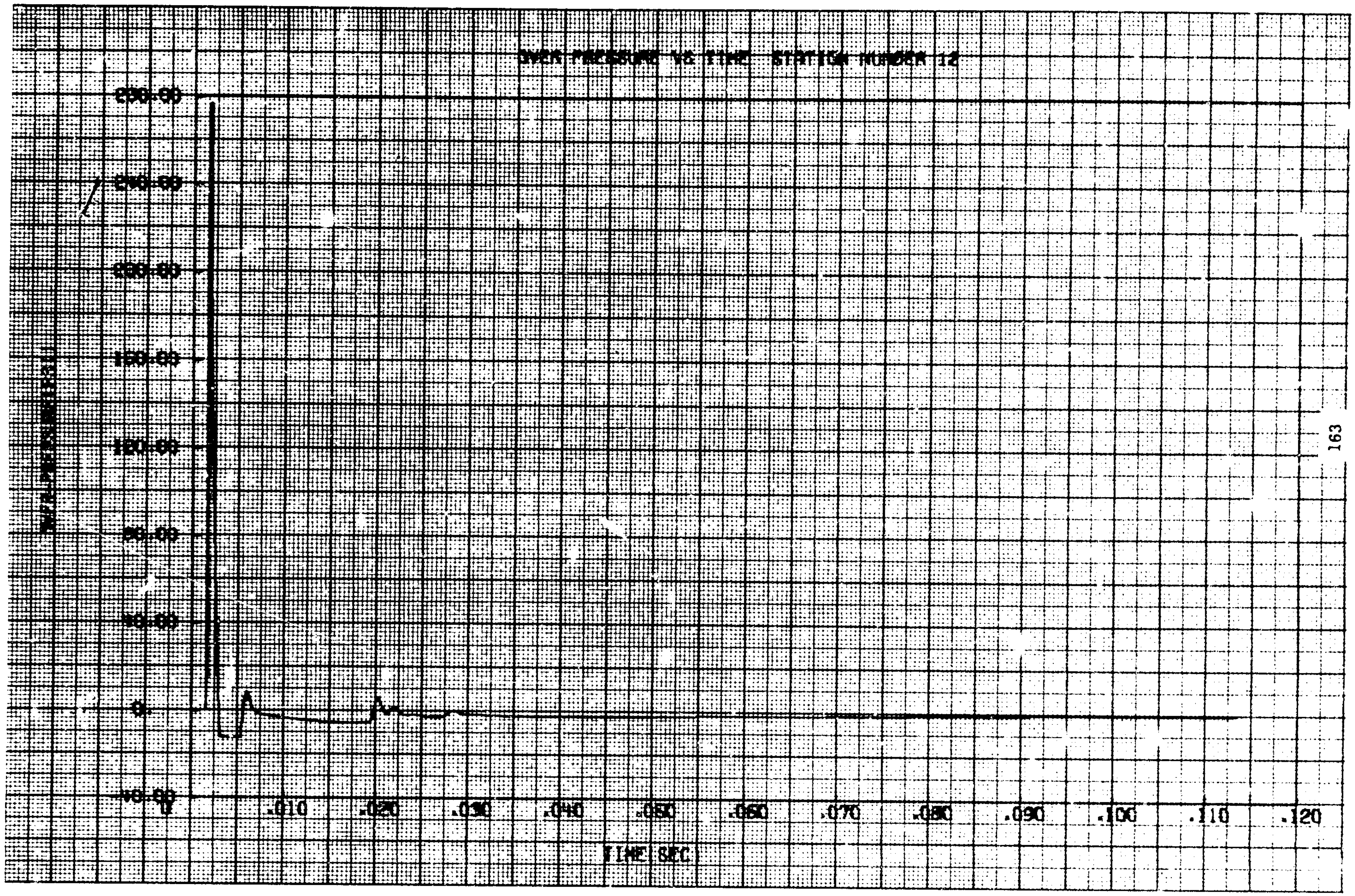

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 11
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC.

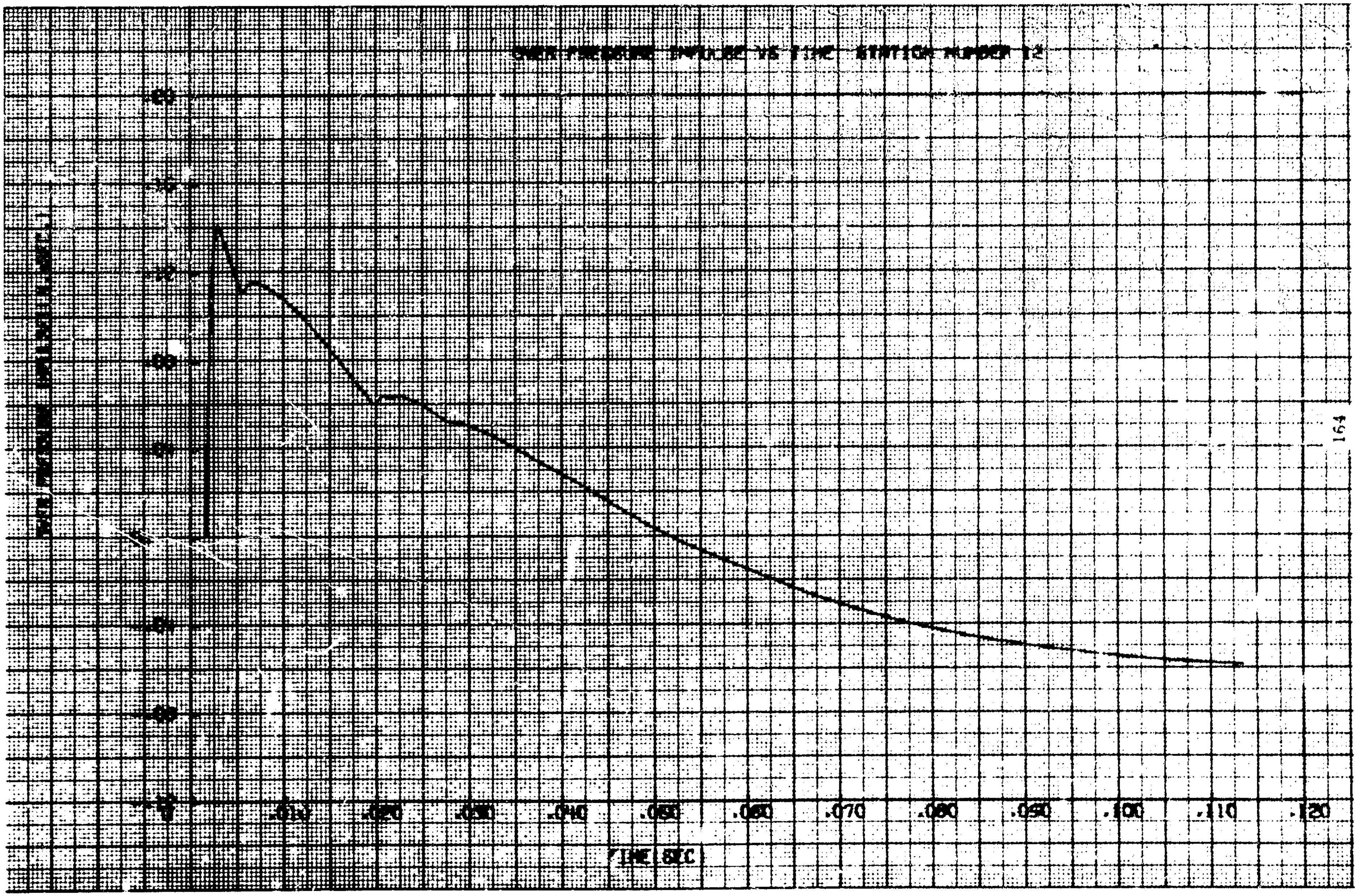

0
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
.140
TIME SEC)

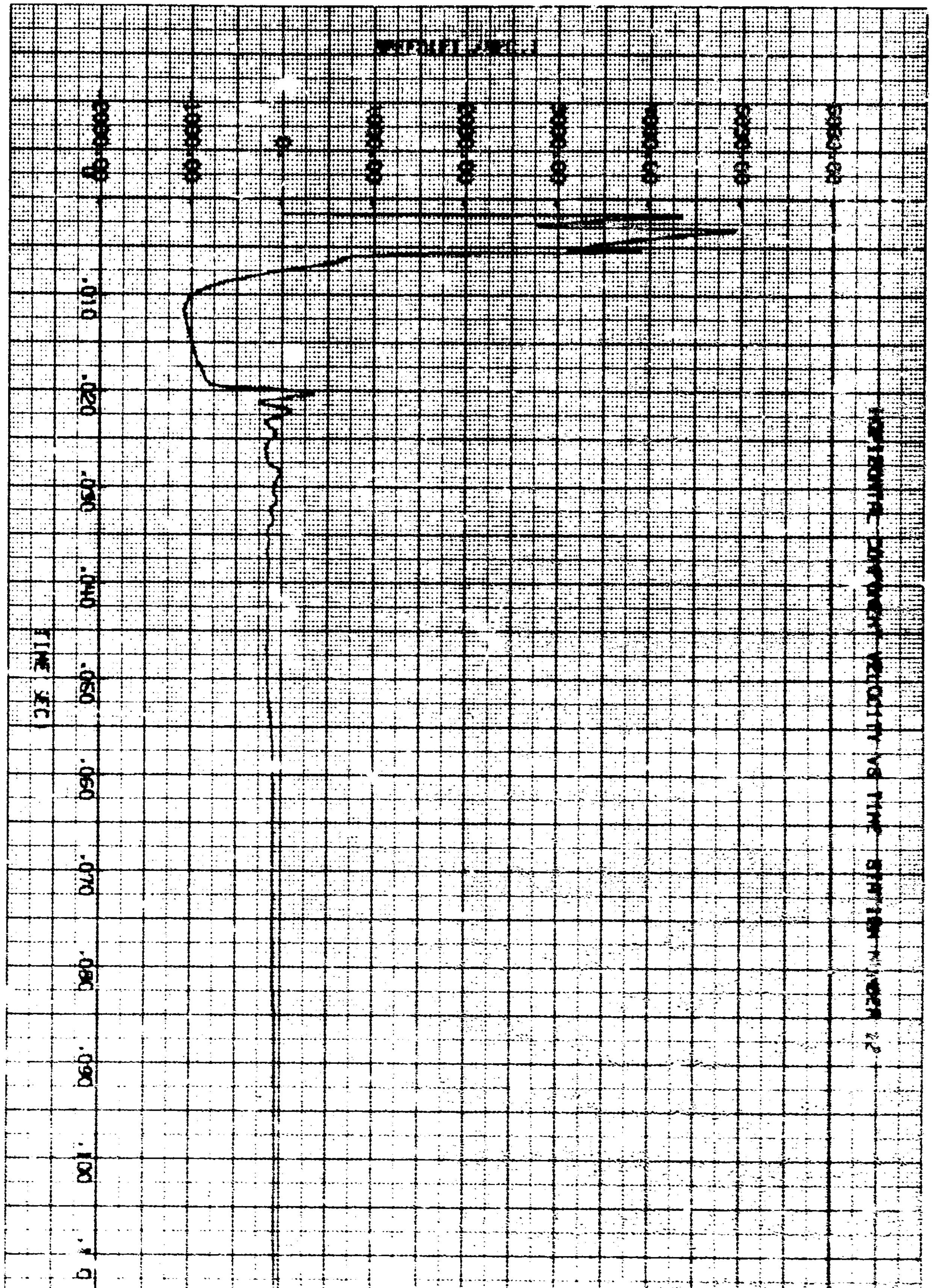
Appendix III

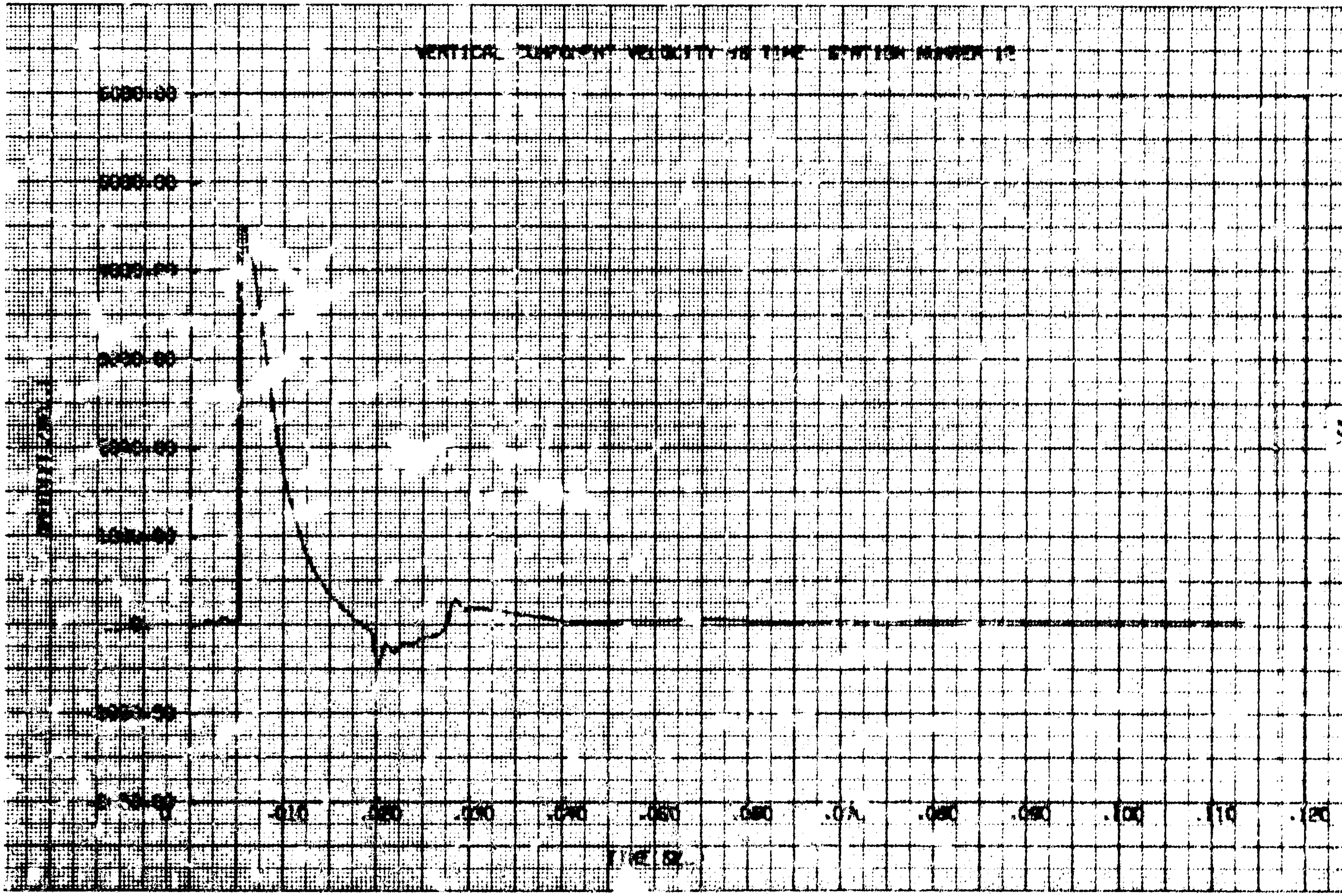
STATION 12 TO 19 PLOTS

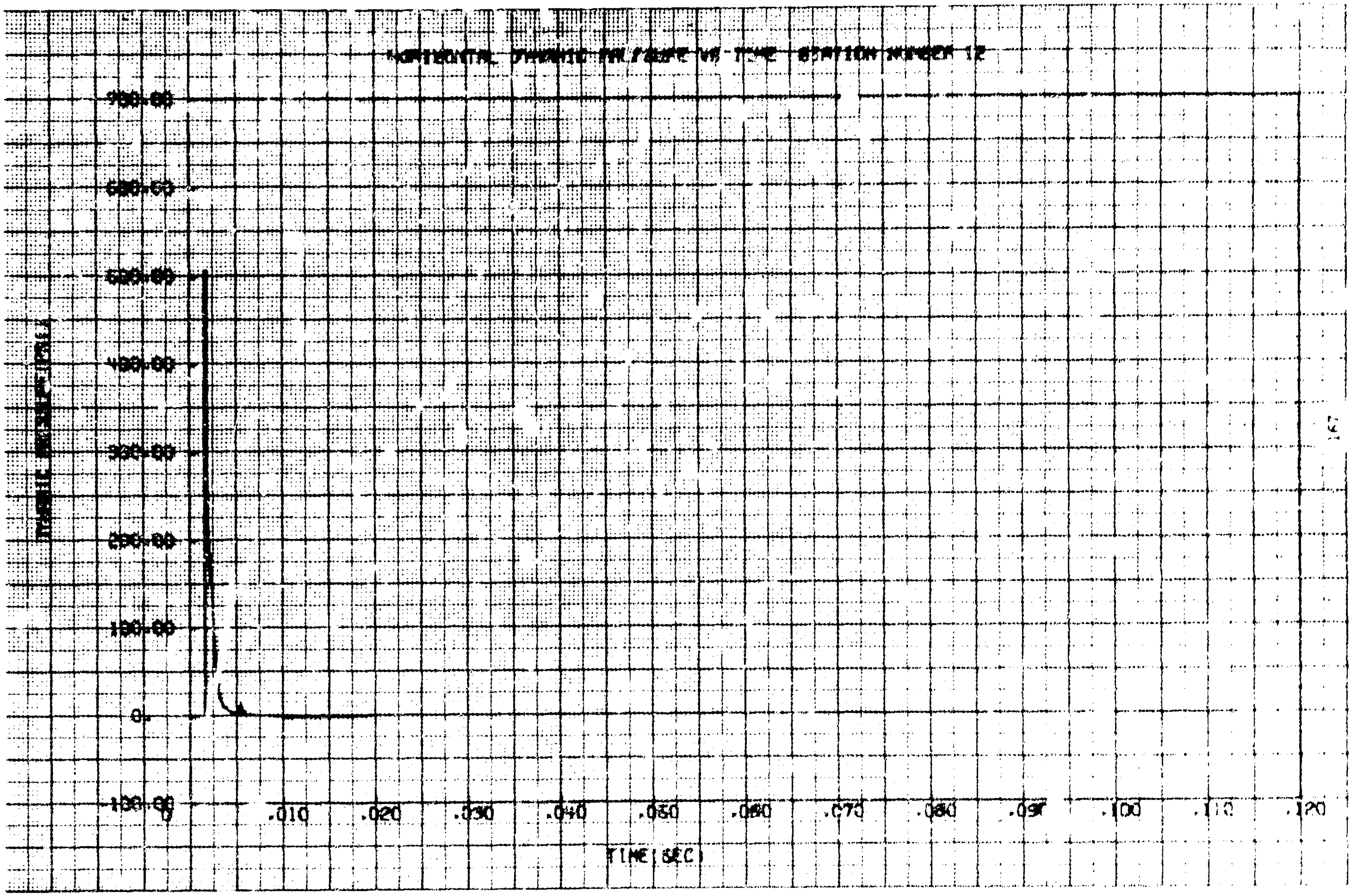
The stations used to obtain these plots were located at burst height with increasing radii.

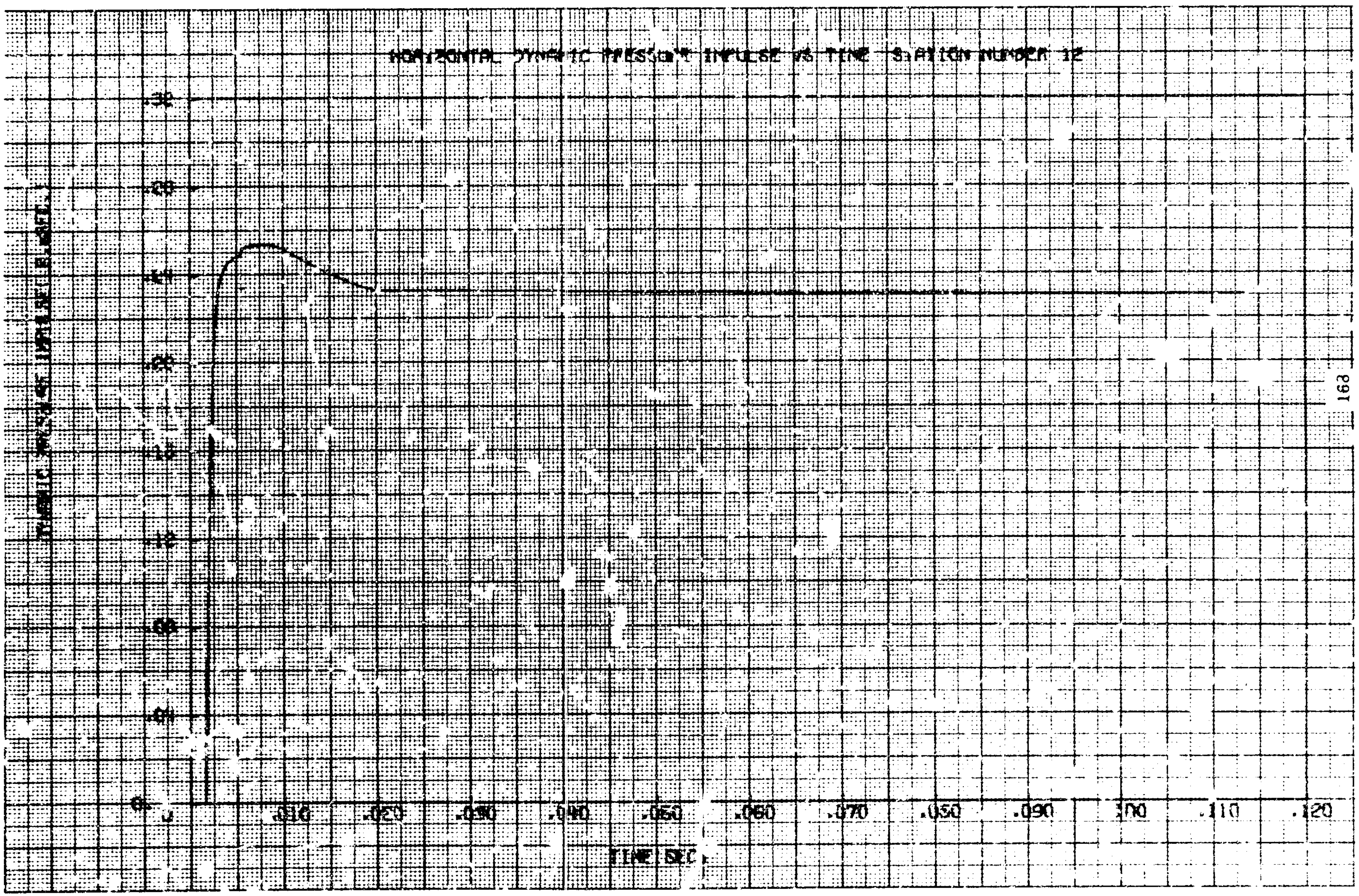

OVER PRESSURE VS TIME STATION NUMBER 12
280.00
240.00
200.00
160.00
120.00
80.00
40.00
0.
-40.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

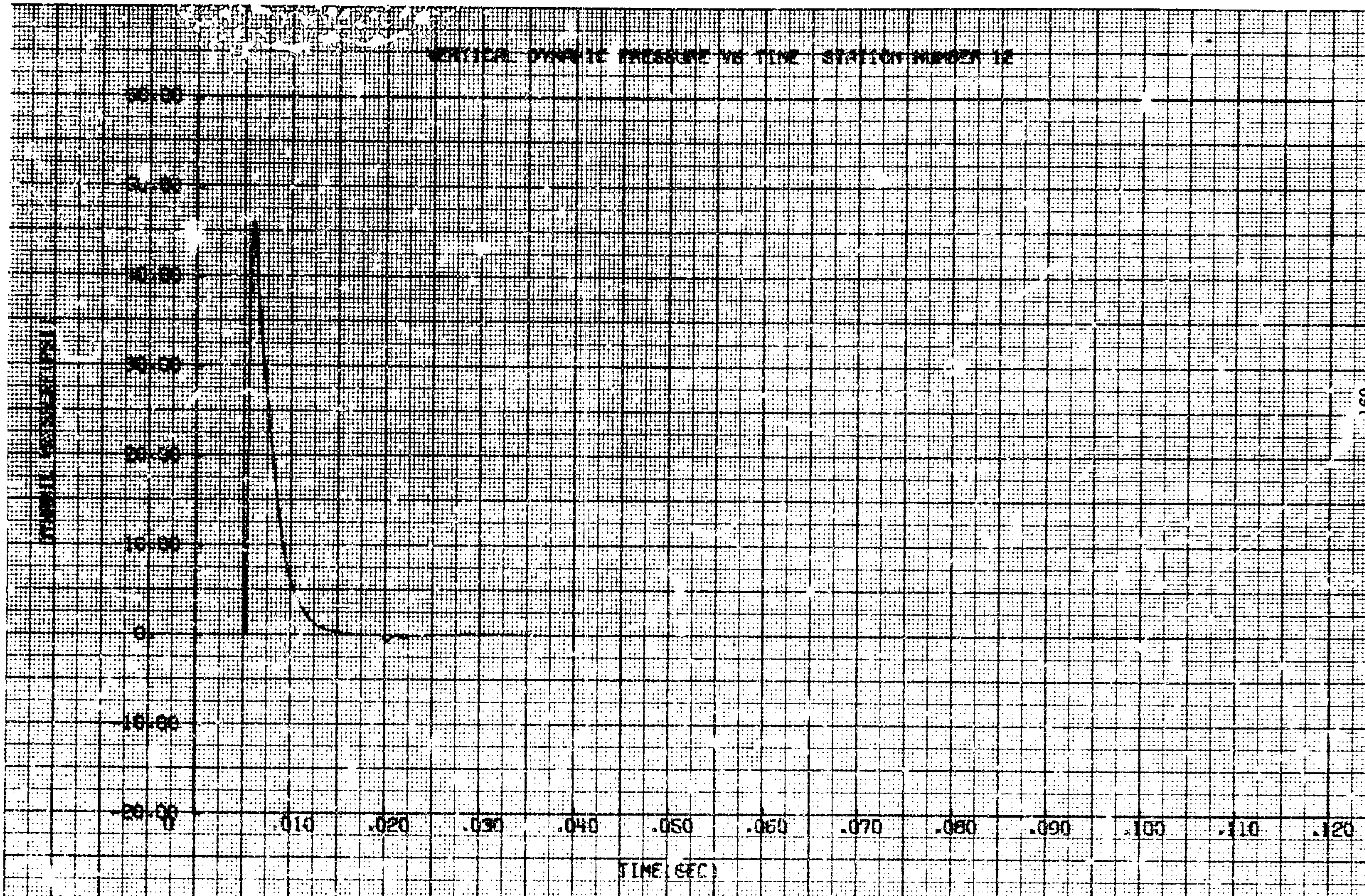

OVER PRESSURE IMPULSE VS TIME STATION NUMBER 12
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

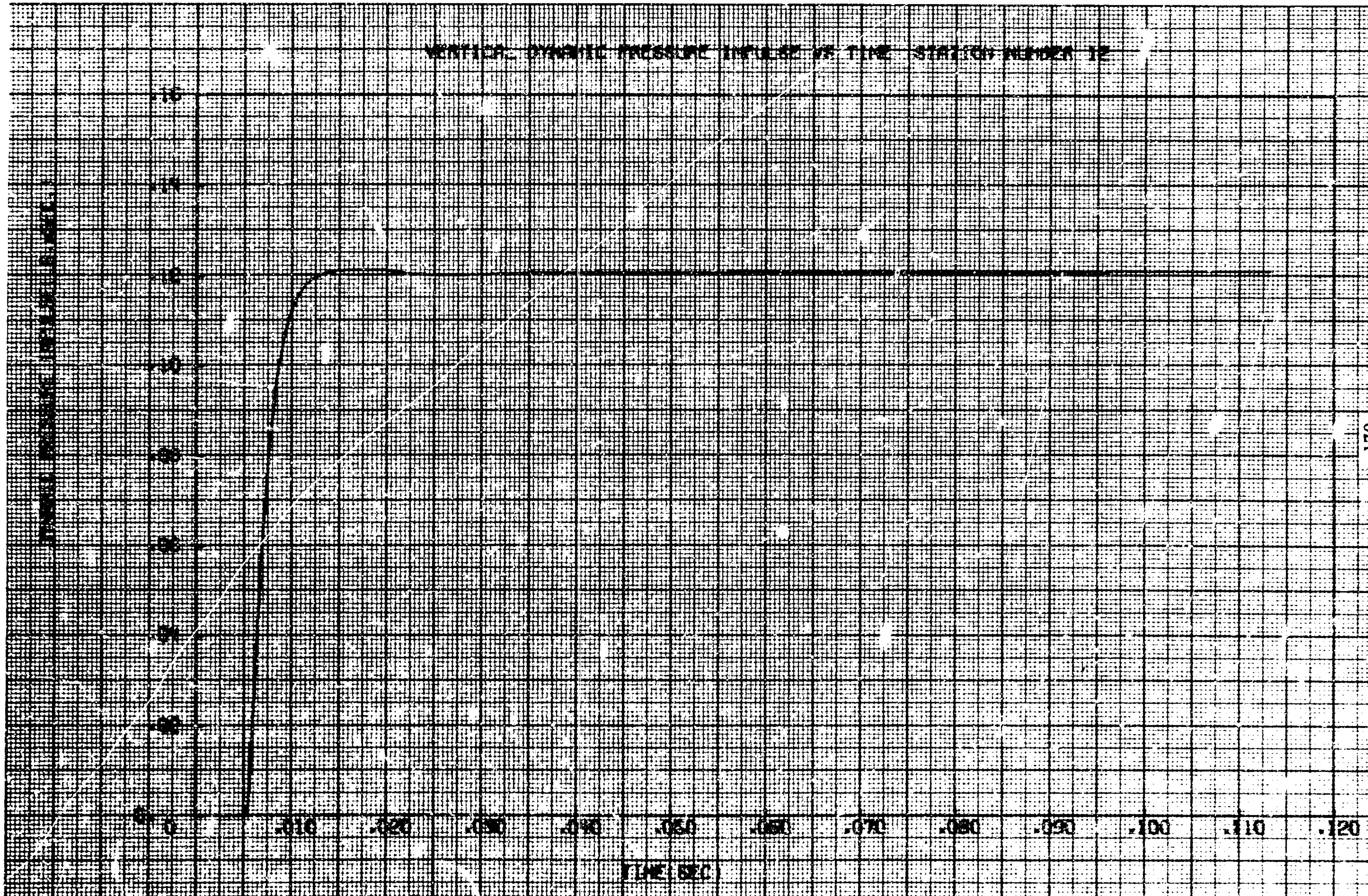

.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.120
TIME (SEC)

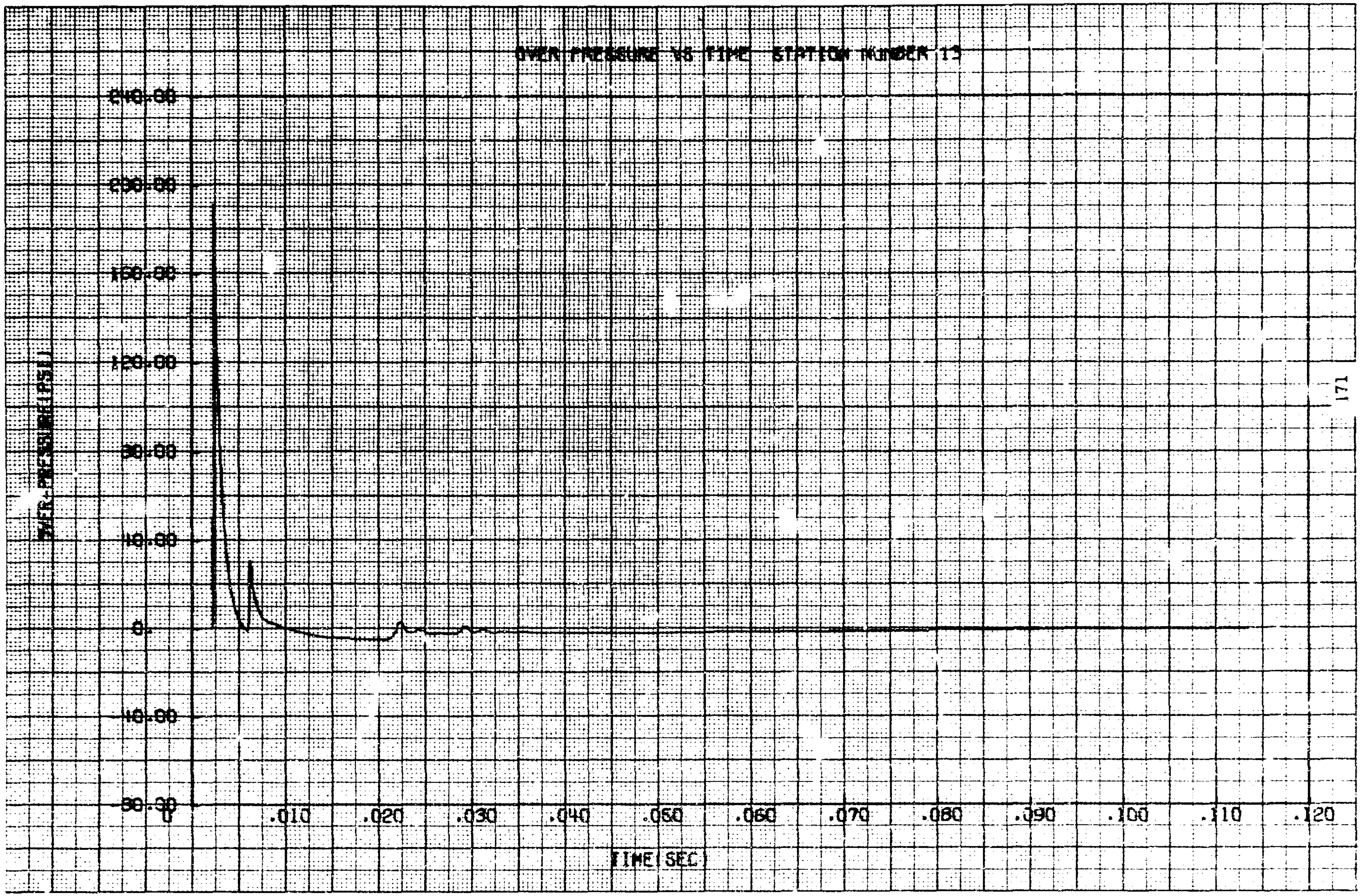

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER
.010
.020
.100
.110
.120

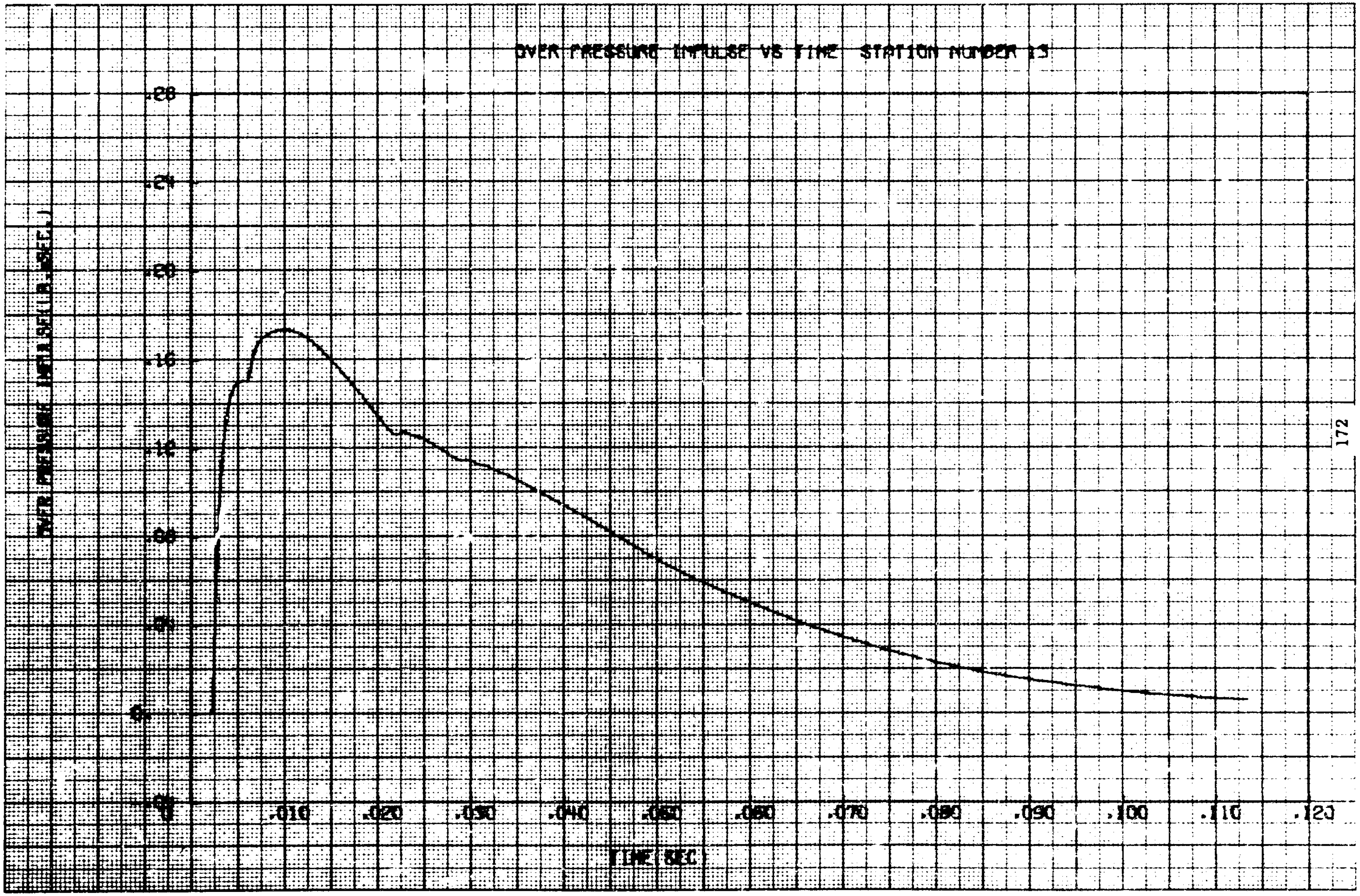

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 12
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.
-100.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)


HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 12
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

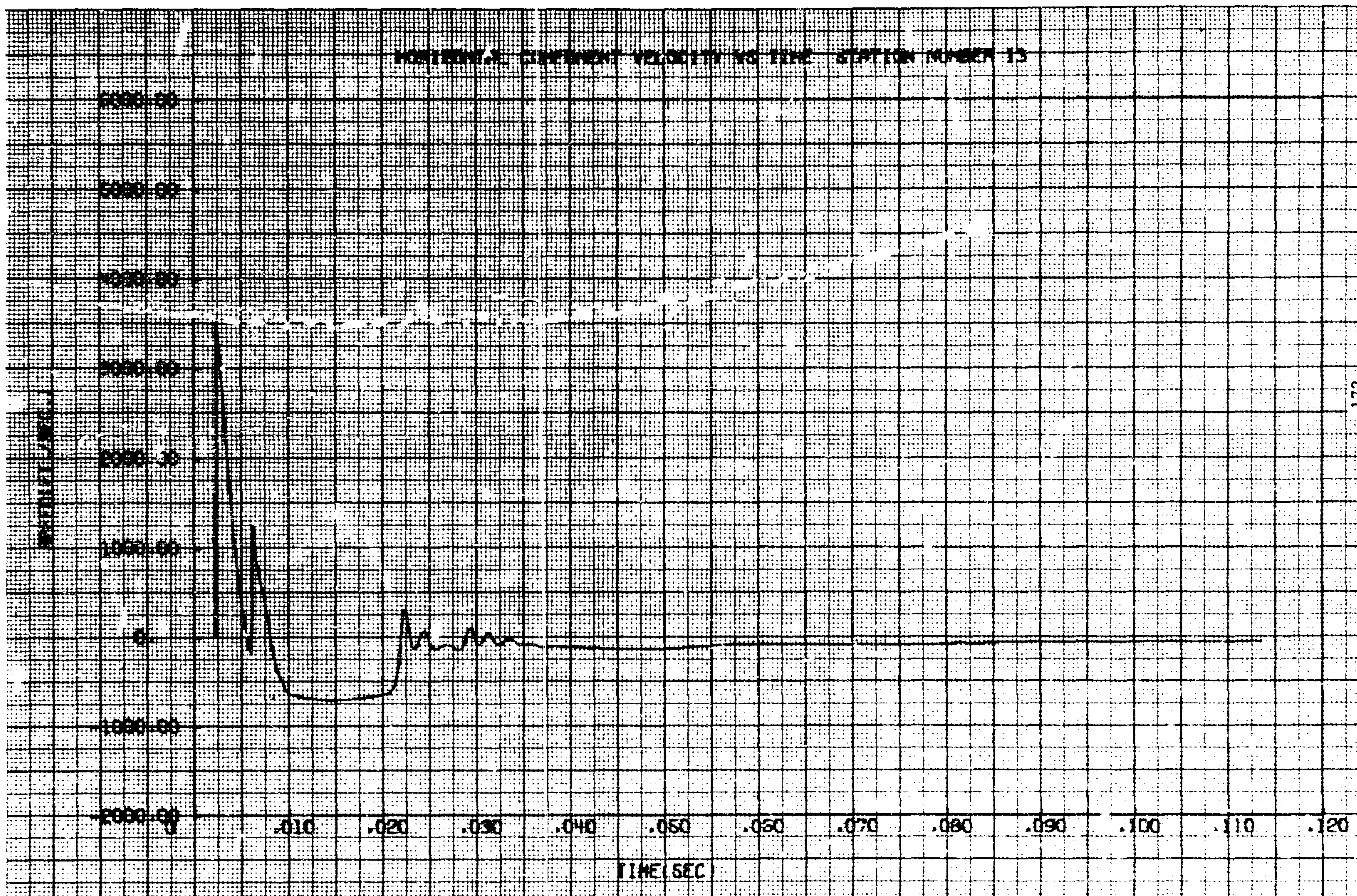

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 12
DYNAMIC PRESSURE (PSI)
60.00
50.00
40.00
30.00
20.00
10.00
0
-10.00
-20.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

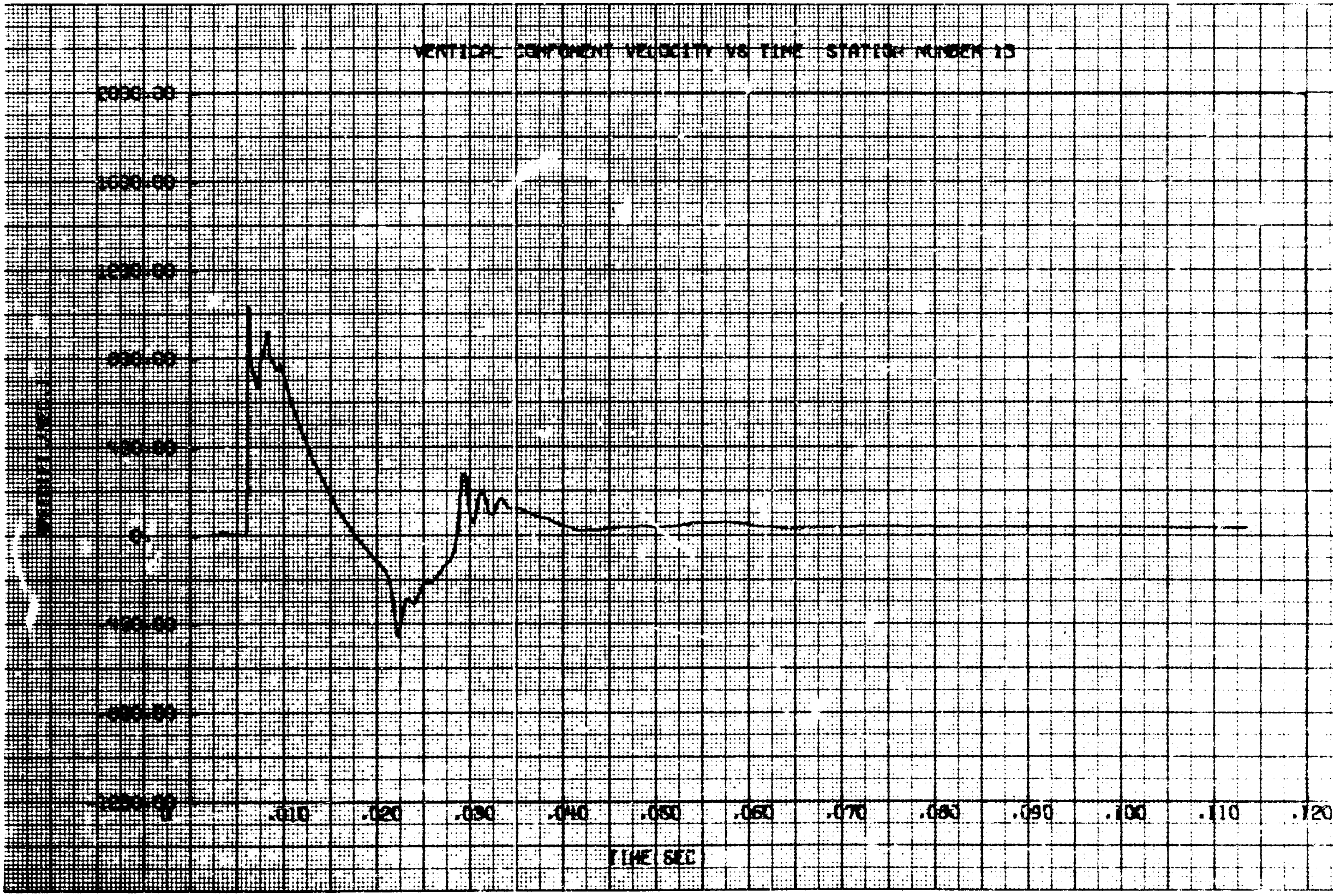

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 12
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

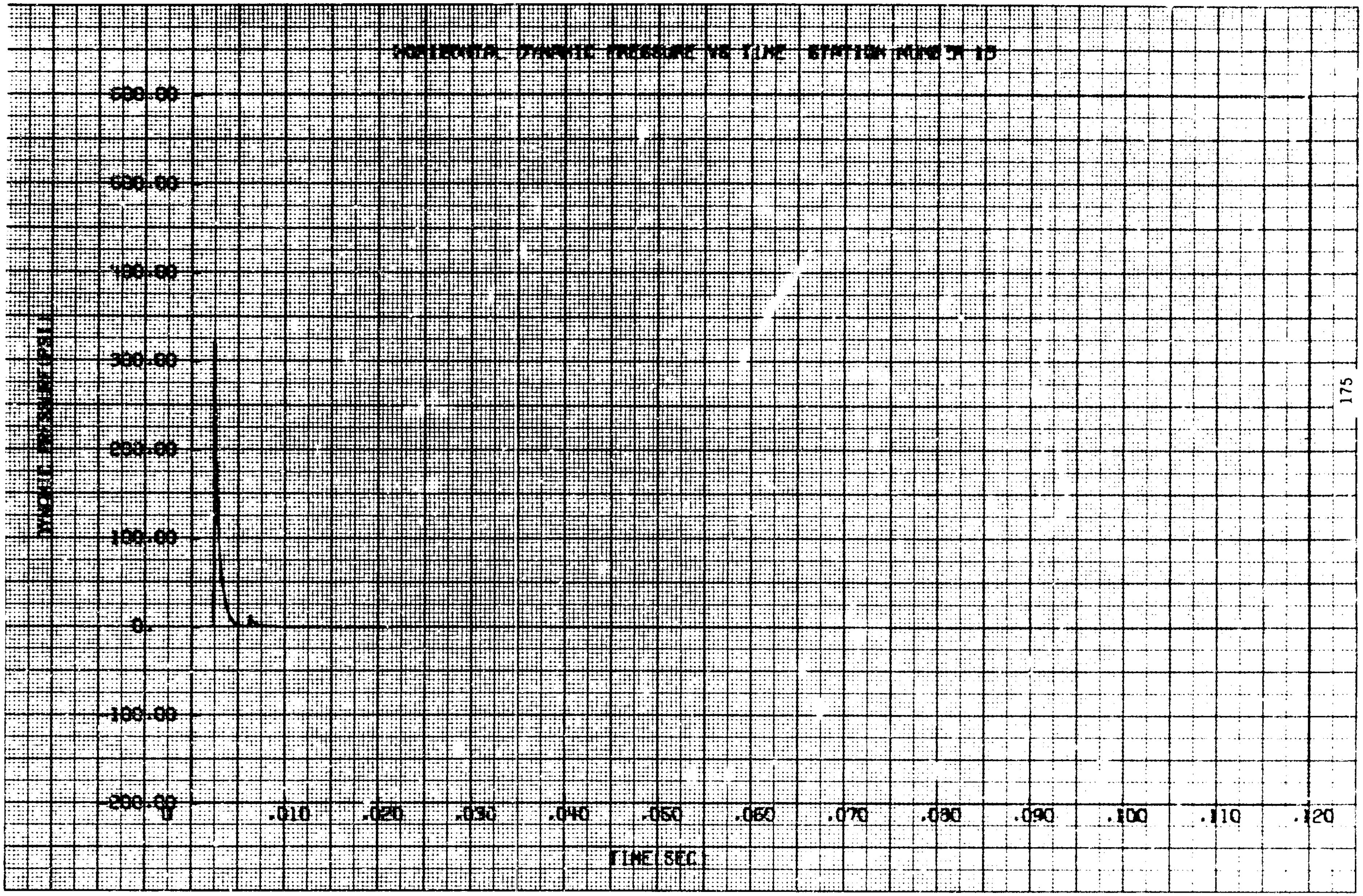

OVER PRESSURE VS TIME STATION NUMBER 13
OVER-PRESSURE(PSI)
240.00
200.00
160.00
120.00
80.00
40.00
0
-40.00
-80.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

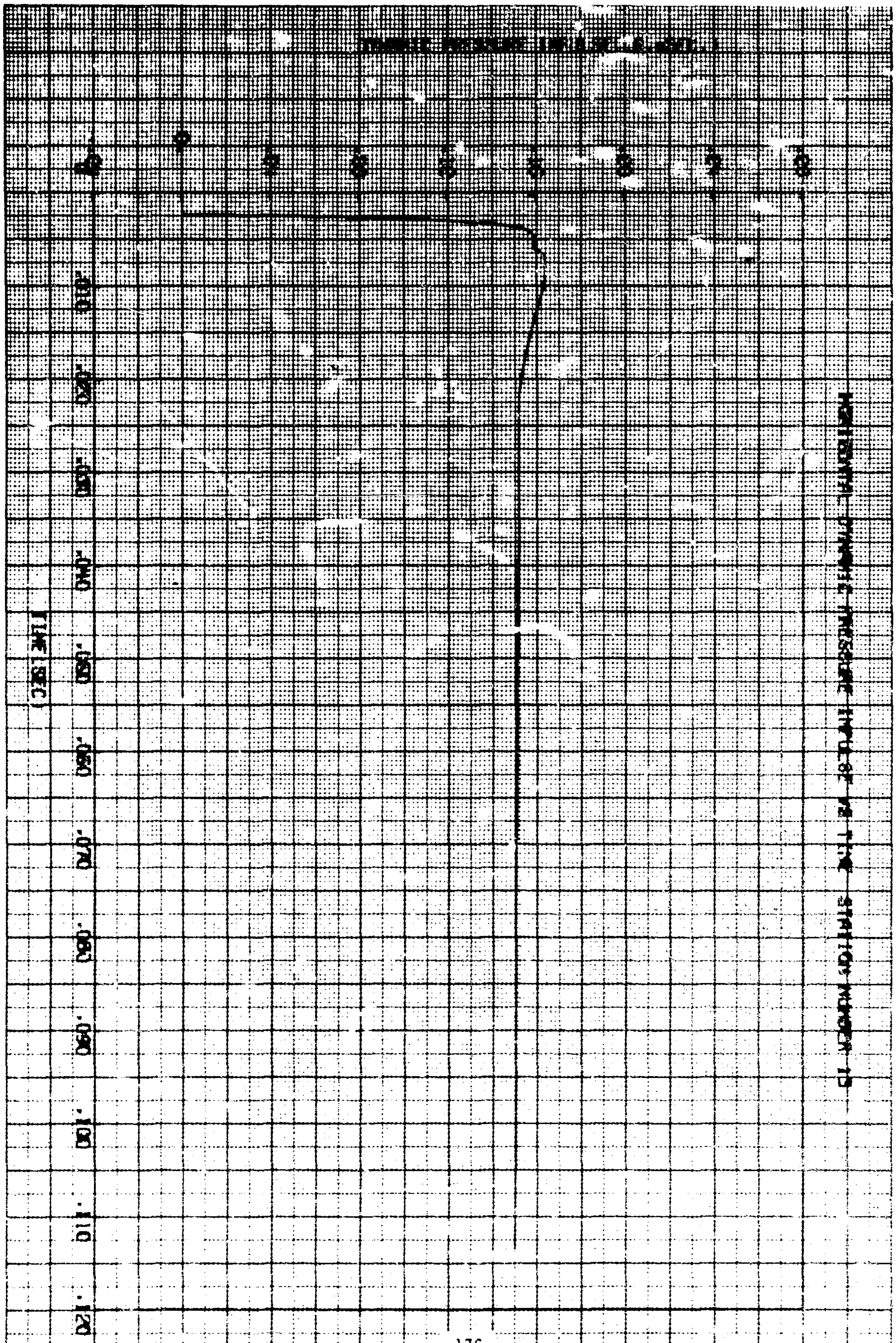


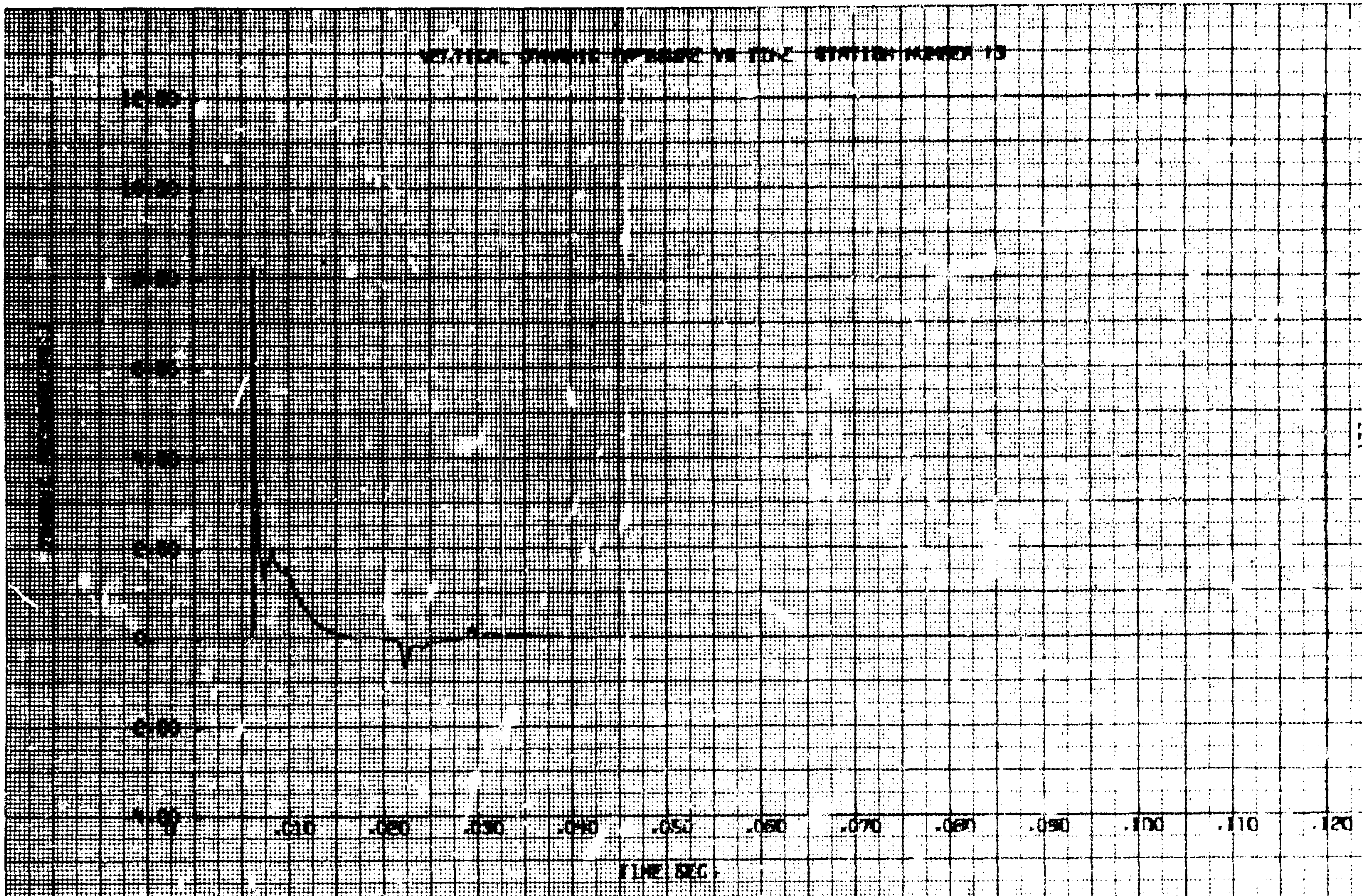
OVER PRESSURE IMPULSE VS TIME STATION NUMBER 13
.28
.24
.20
.16
.12
.08
.04
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

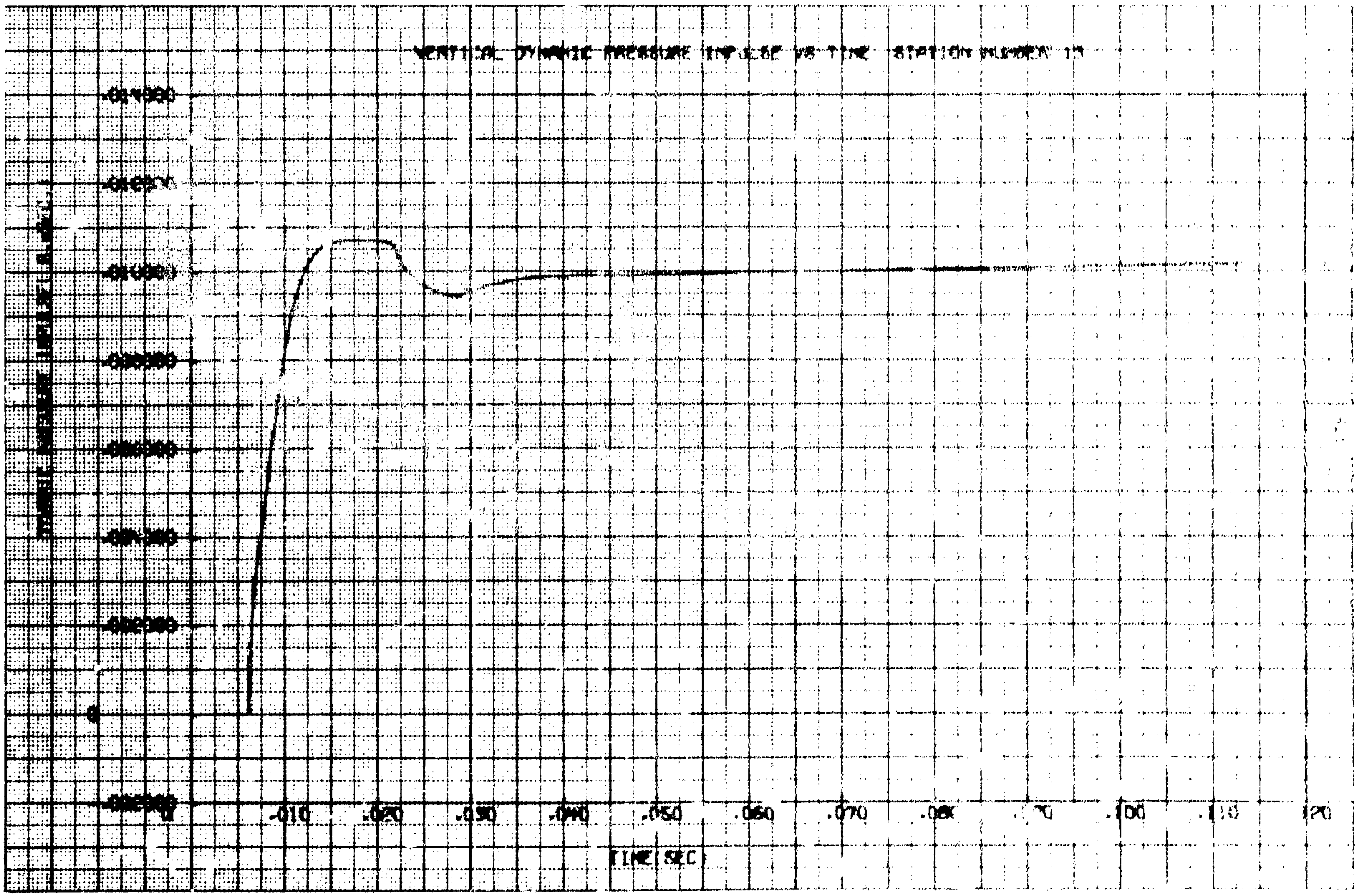

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 13
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0
-1000.00
-2000.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)


VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER 13
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

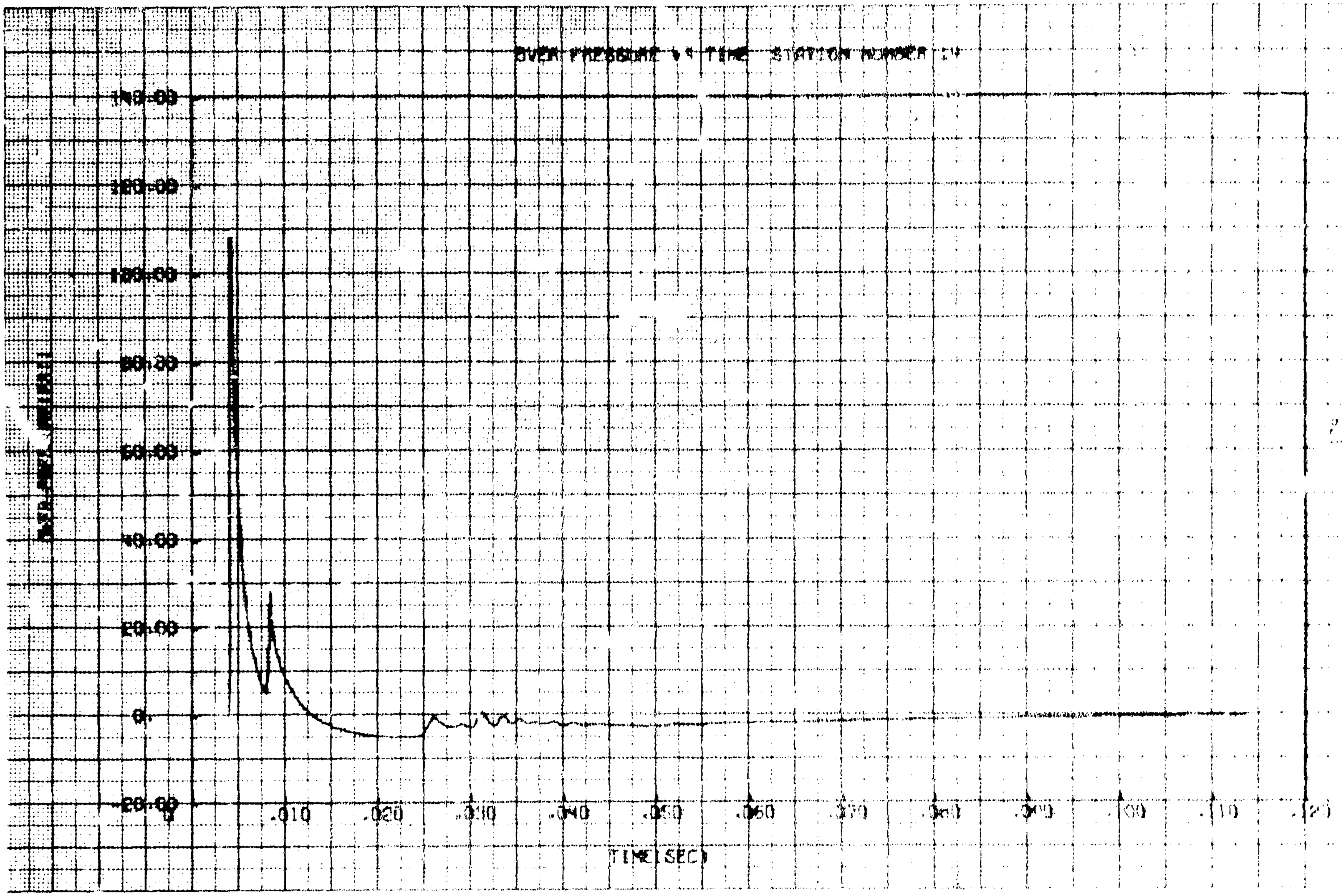

DYNAMIC PRESSURE(PSI)
600.00
500.00
400.00
300.00
200.00
100.00
0.
-100.00
-200.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC.

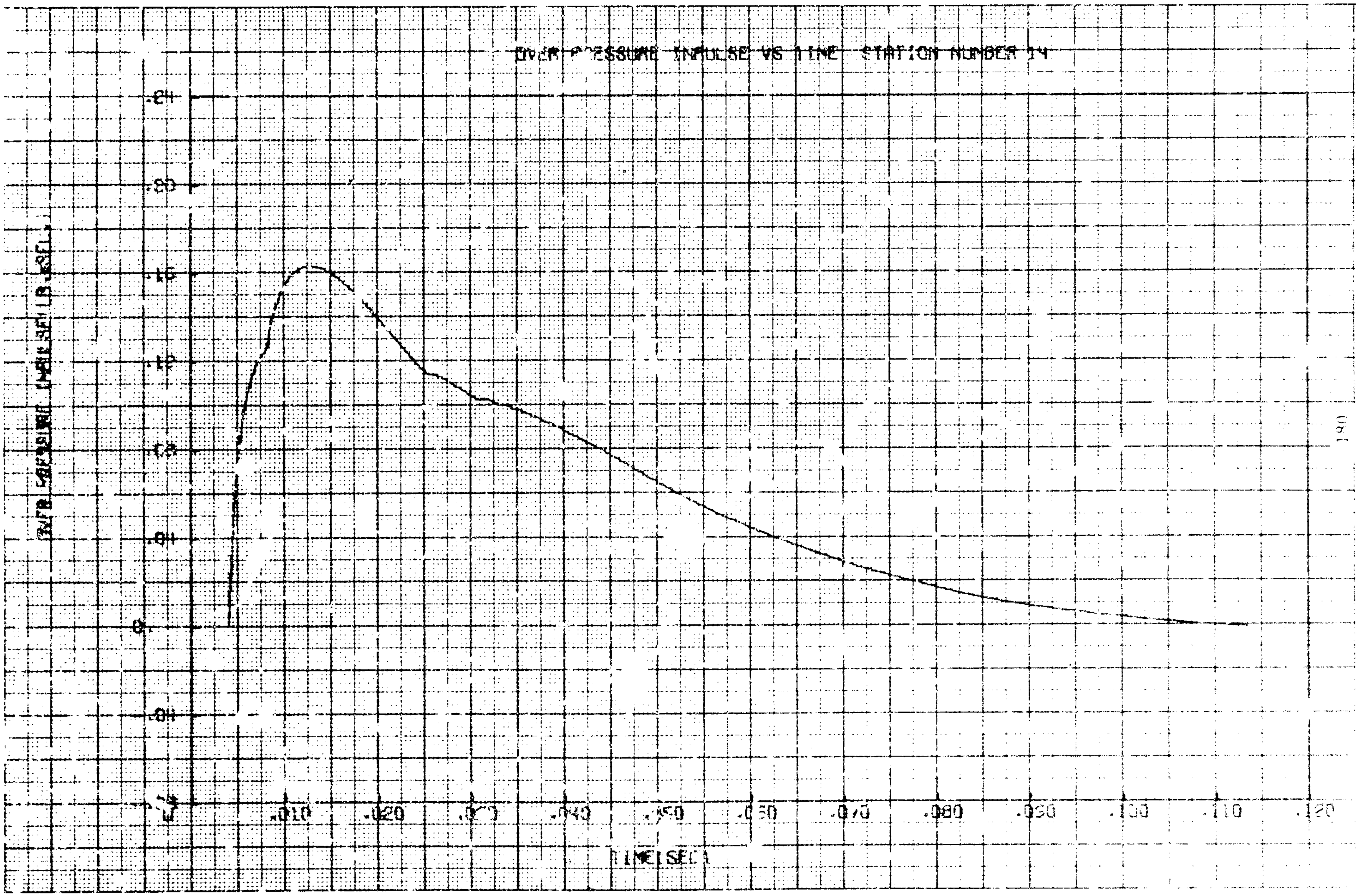

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 13
TIME (SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

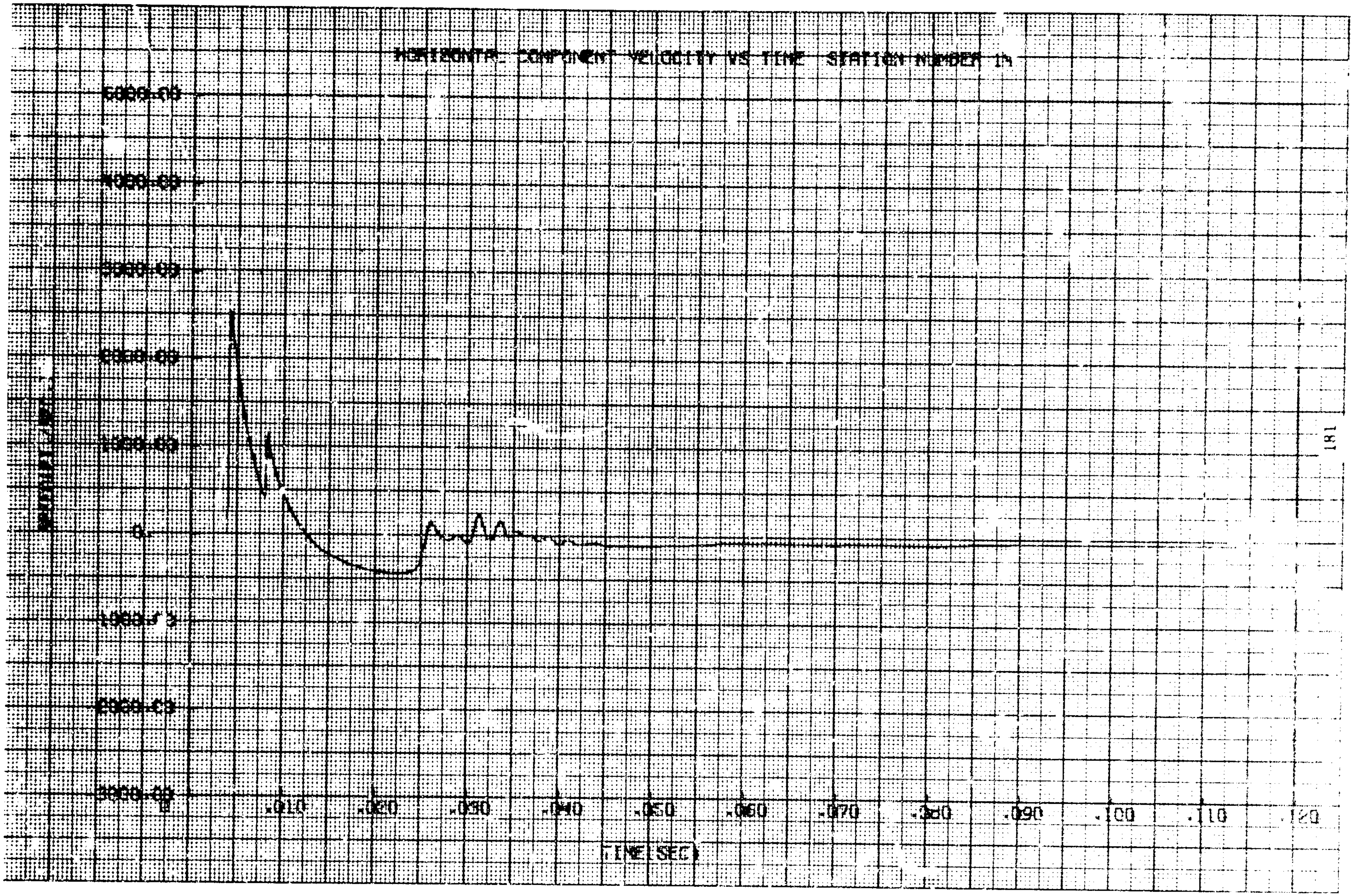

.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

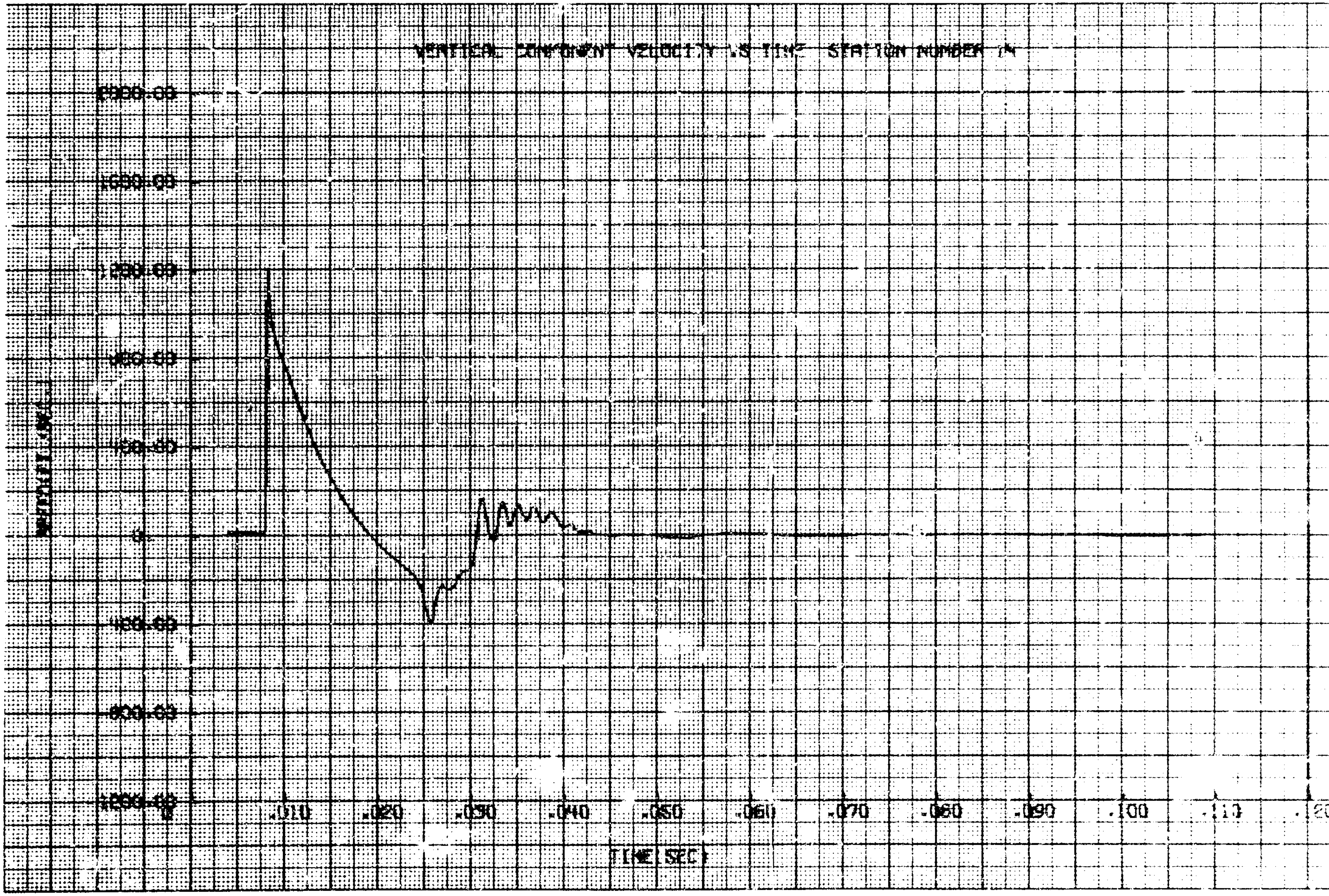


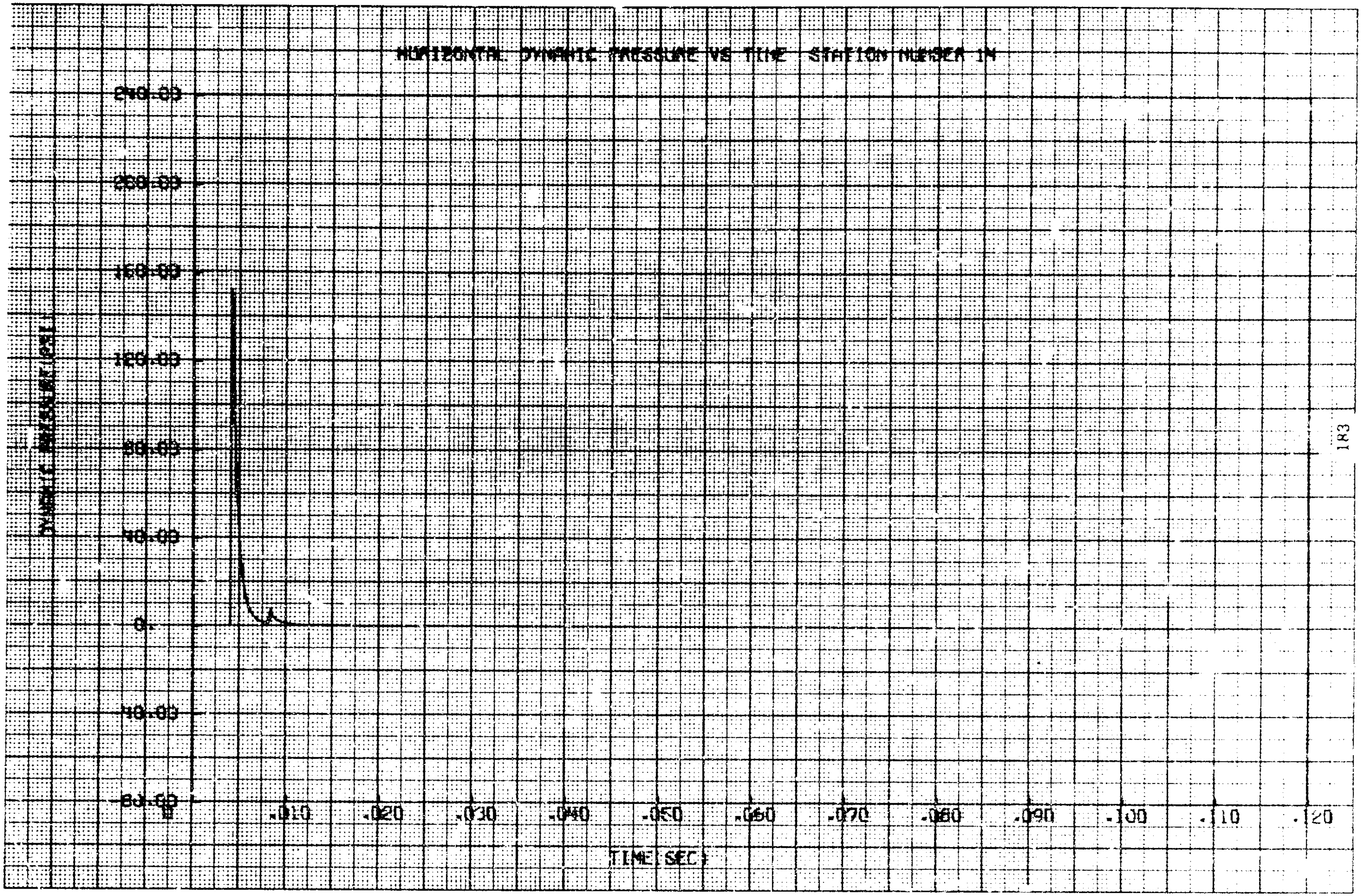
VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 13
0
.010
.020
.030
.040
.050
.060
.070
.100
TIME (SEC)

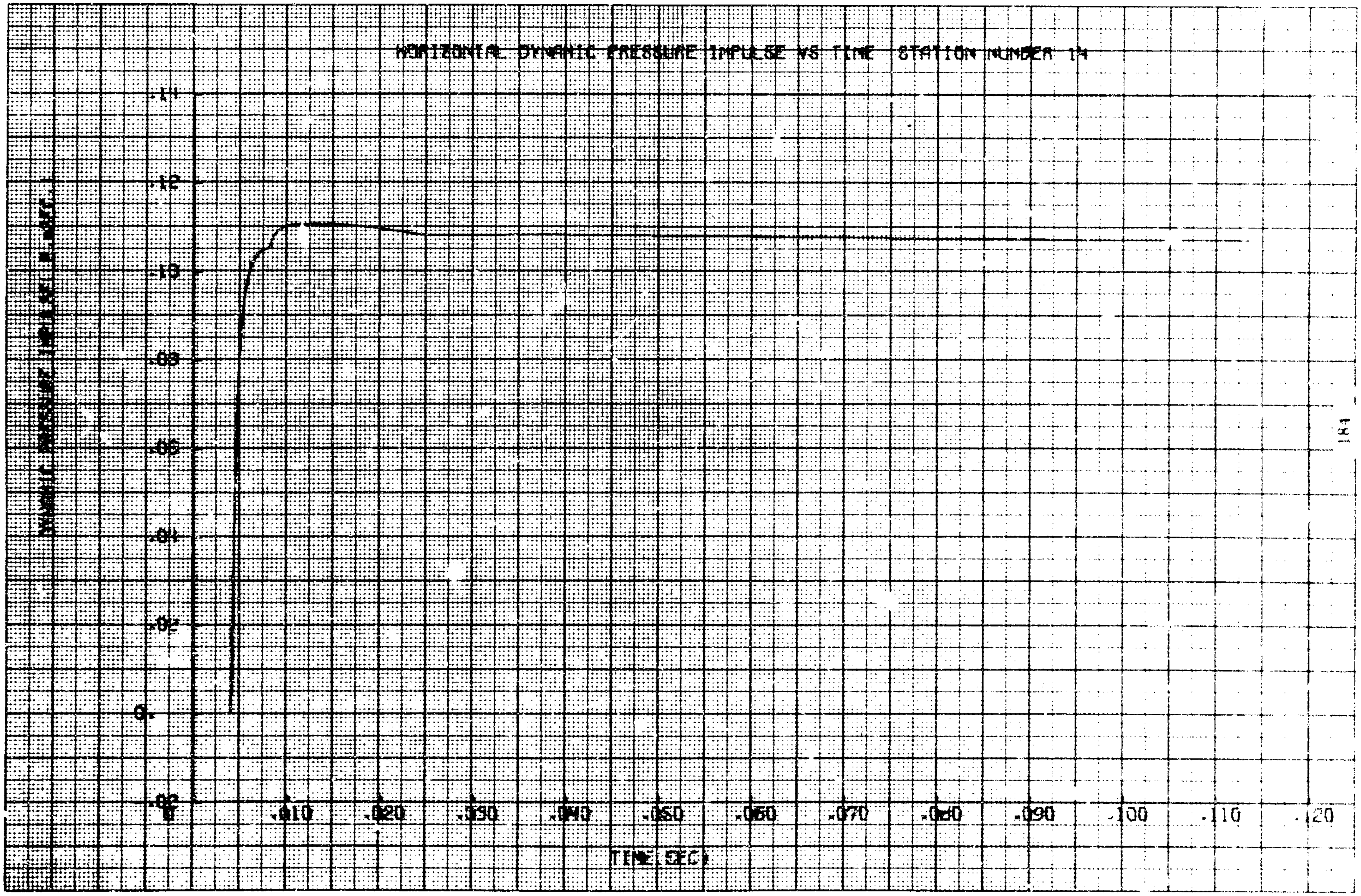

OVER PRESSURE VS TIME STATION NUMBER
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.
-20.00
0
.010
.020
.030
.040
.050
.060
TIME(SEC)

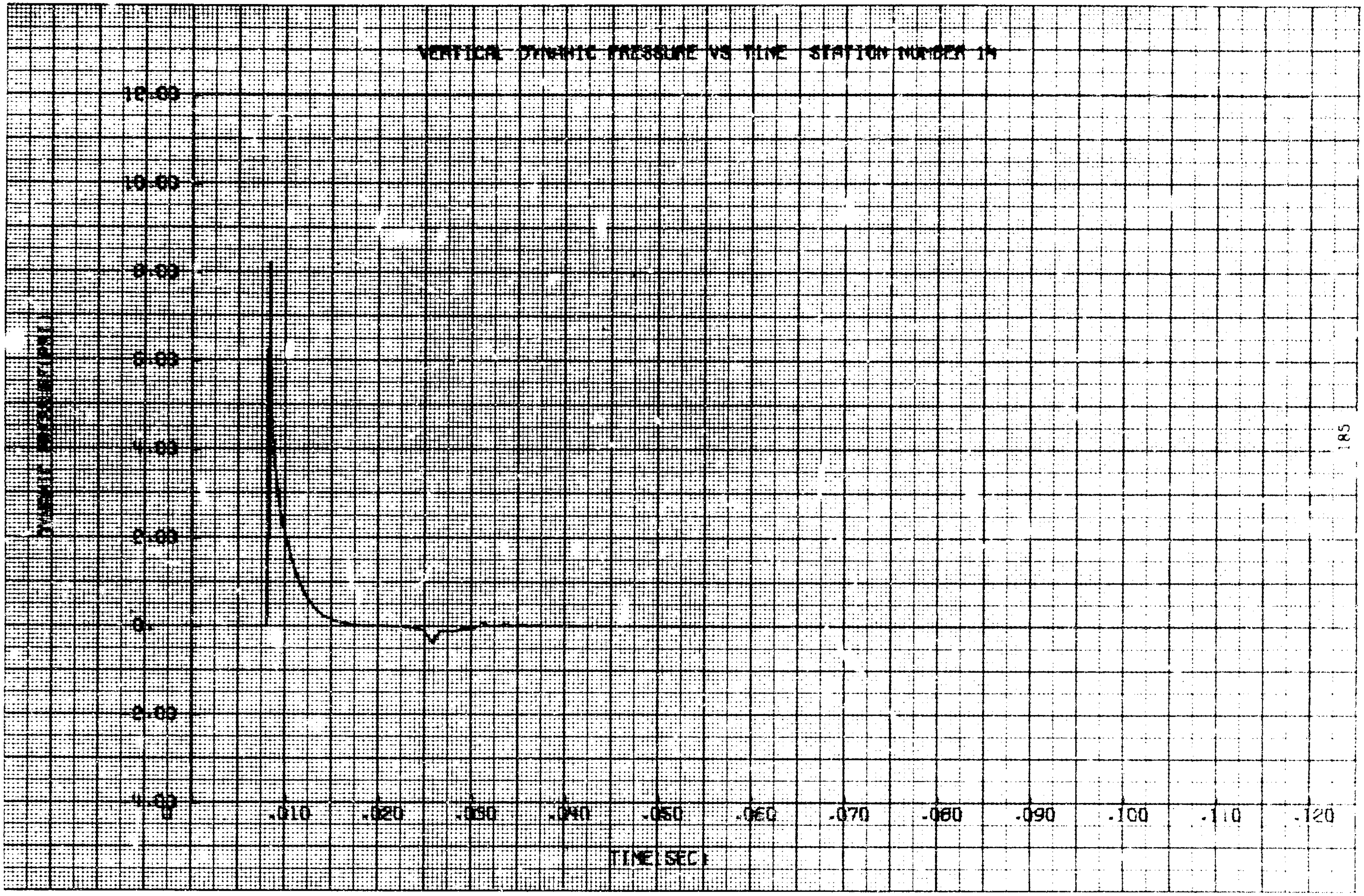

OVER PRESSURE IMPULSE VS TIME STATION NUMBER 14
OVER PRESSURE IMPULSE(LB.-SEC.)
.24
.20
.16
.12
.08
.04
0
-.04
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

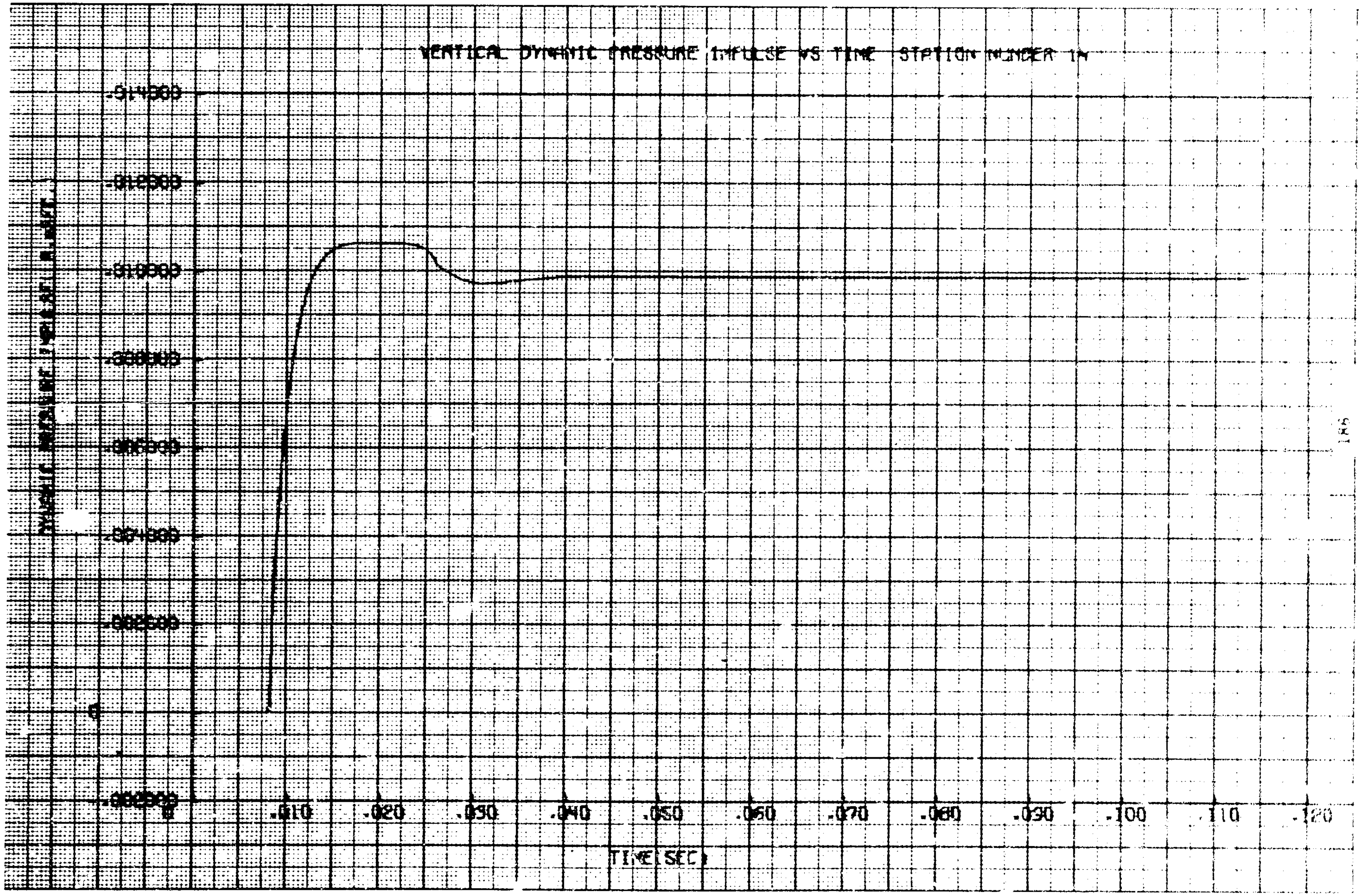

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 14
5000.00
4000.00
3000.00
2000.00
1000.00
0.
-1000.00
-2000.00
-3000.00
0.
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

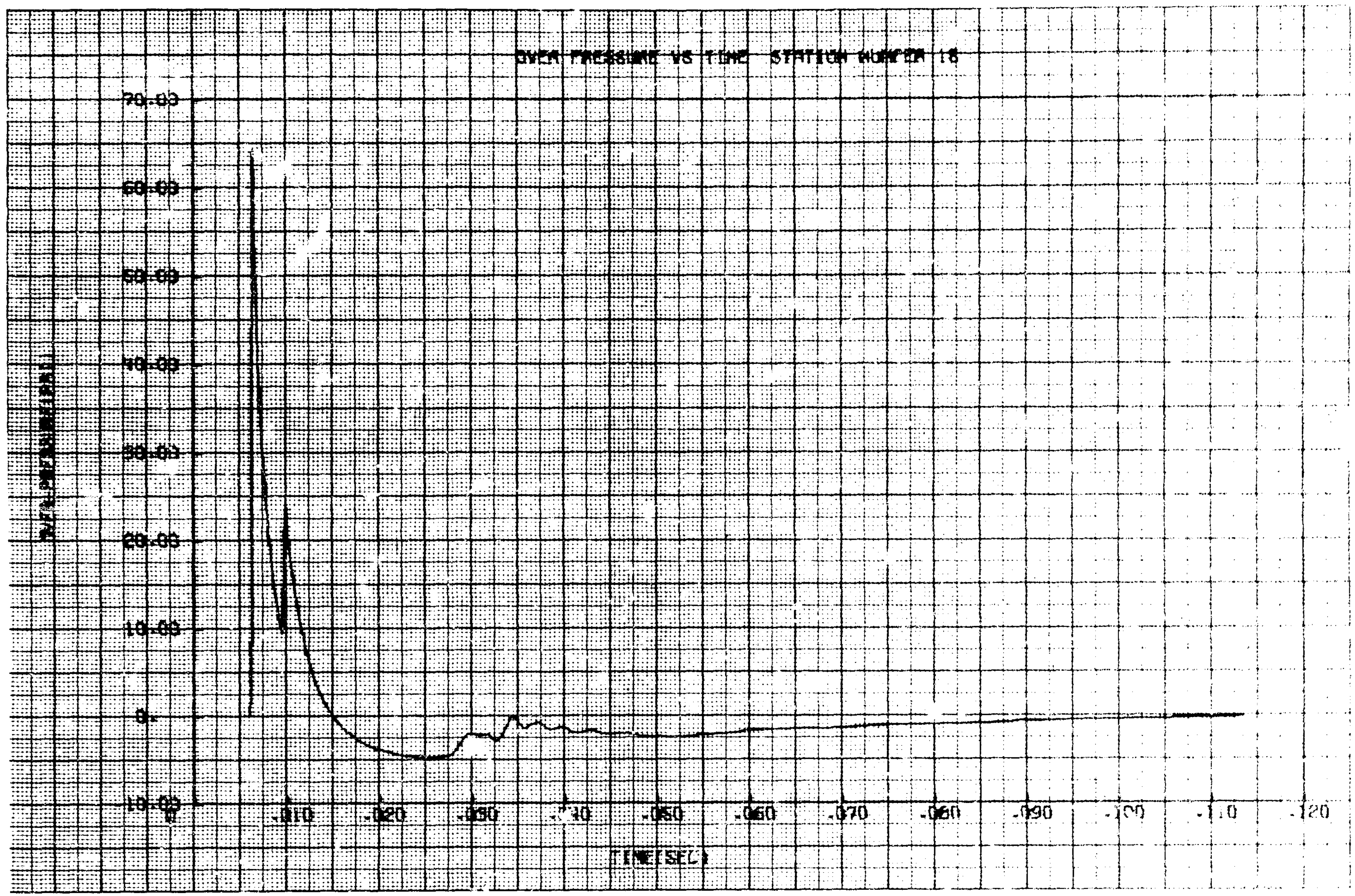

VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
TIME(SEC)

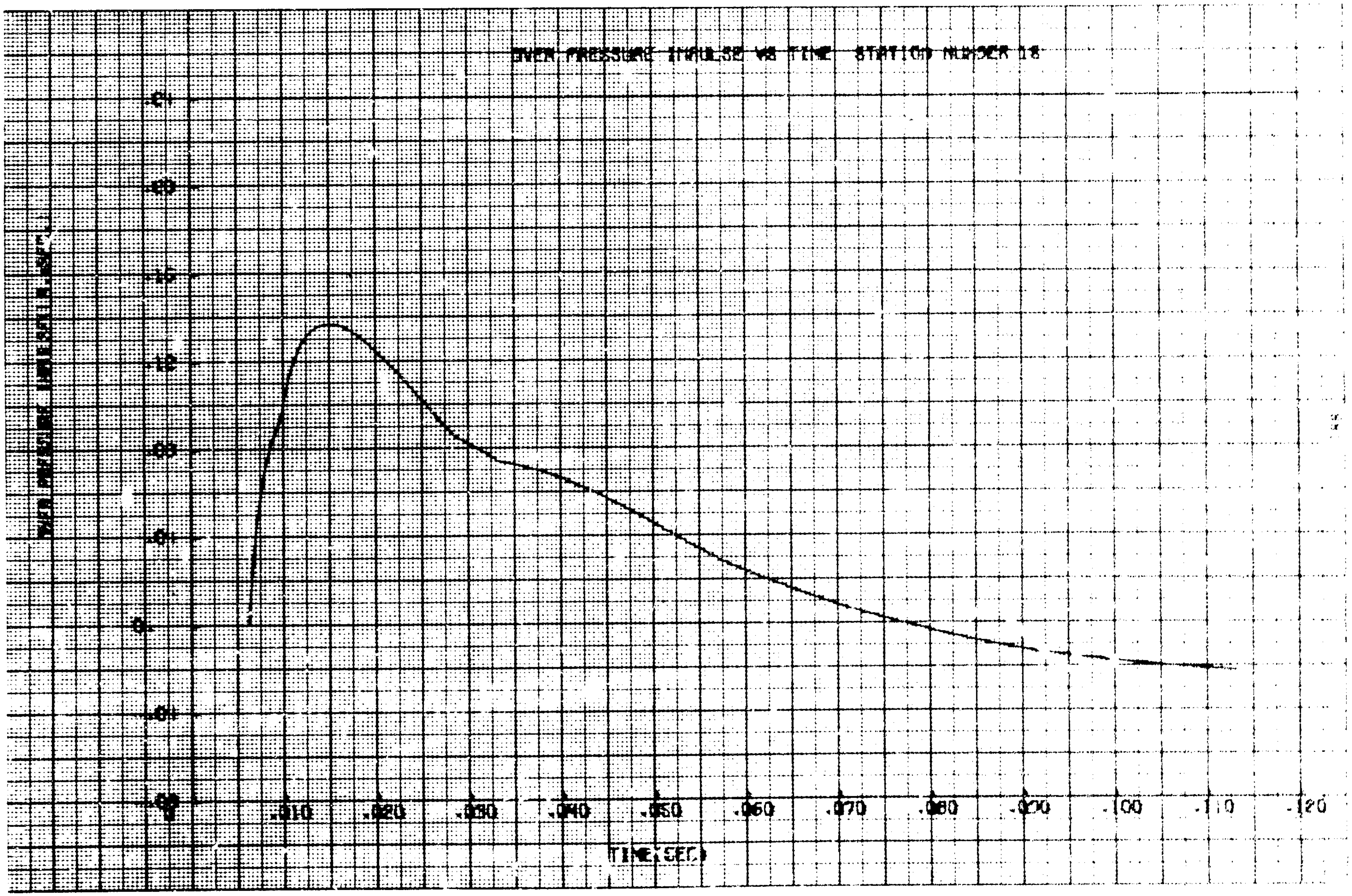

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 14
DYNAMIC PRESSURE (PSI)
240.00
200.00
160.00
120.00
80.00
40.00
0.
-40.00
-80.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

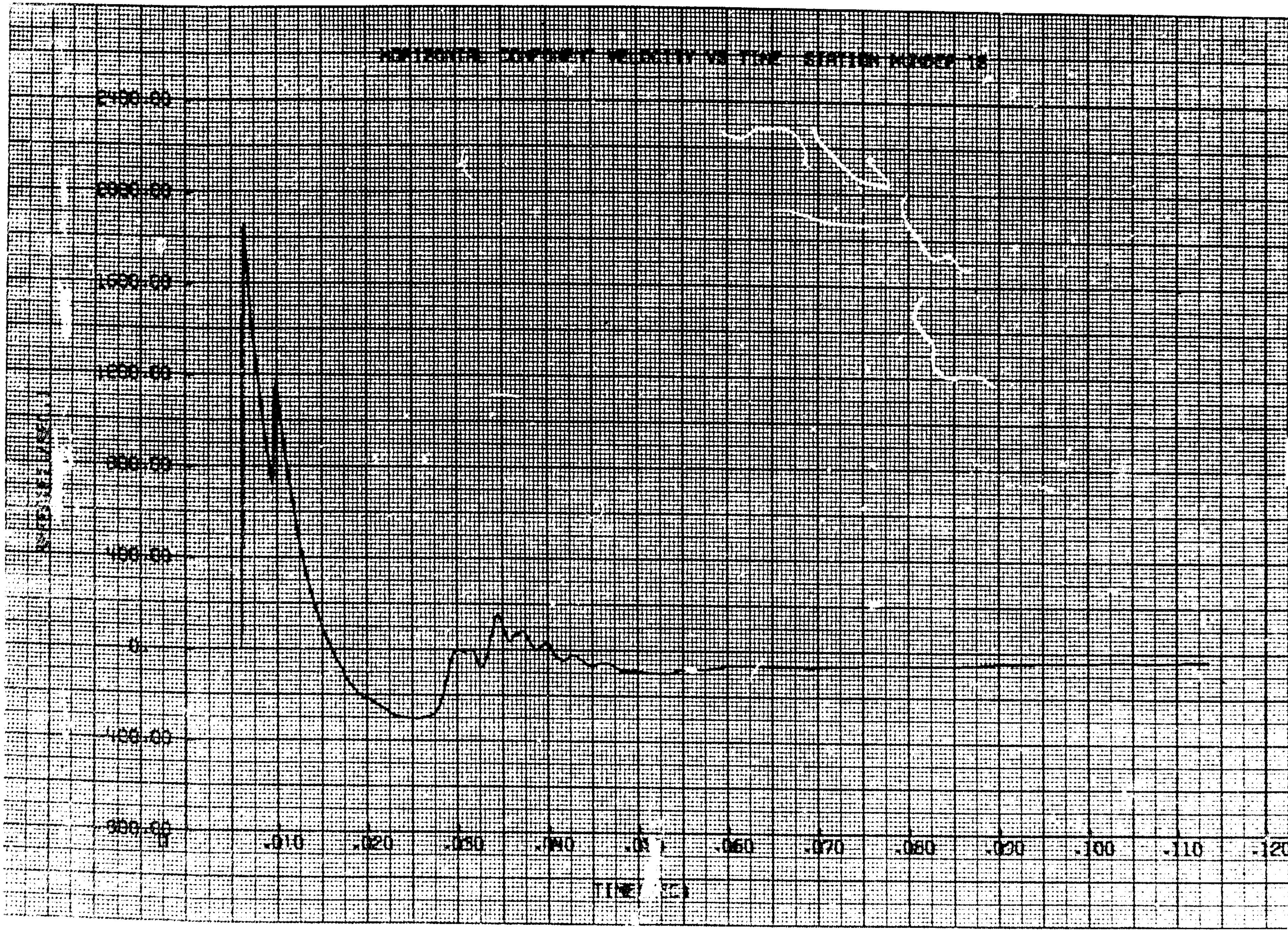

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 14
.14
.12
.10
.08
.06
.04
.02
0
-.02
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

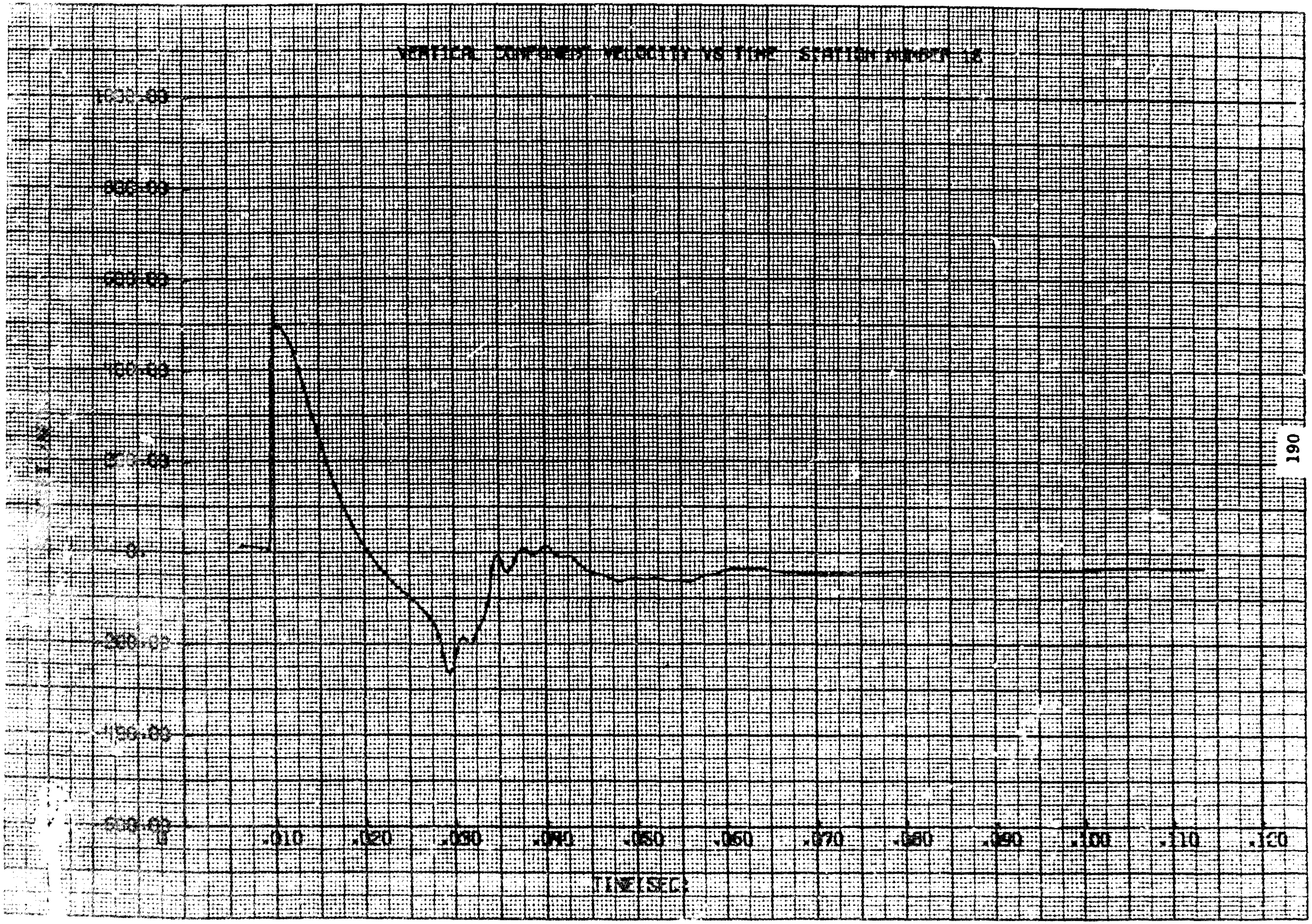

VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 14
DYNAMIC PRESSURE(PSI)
12.00
10.00
8.00
6.00
4.00
2.00
0.
-2.00
-4.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC)

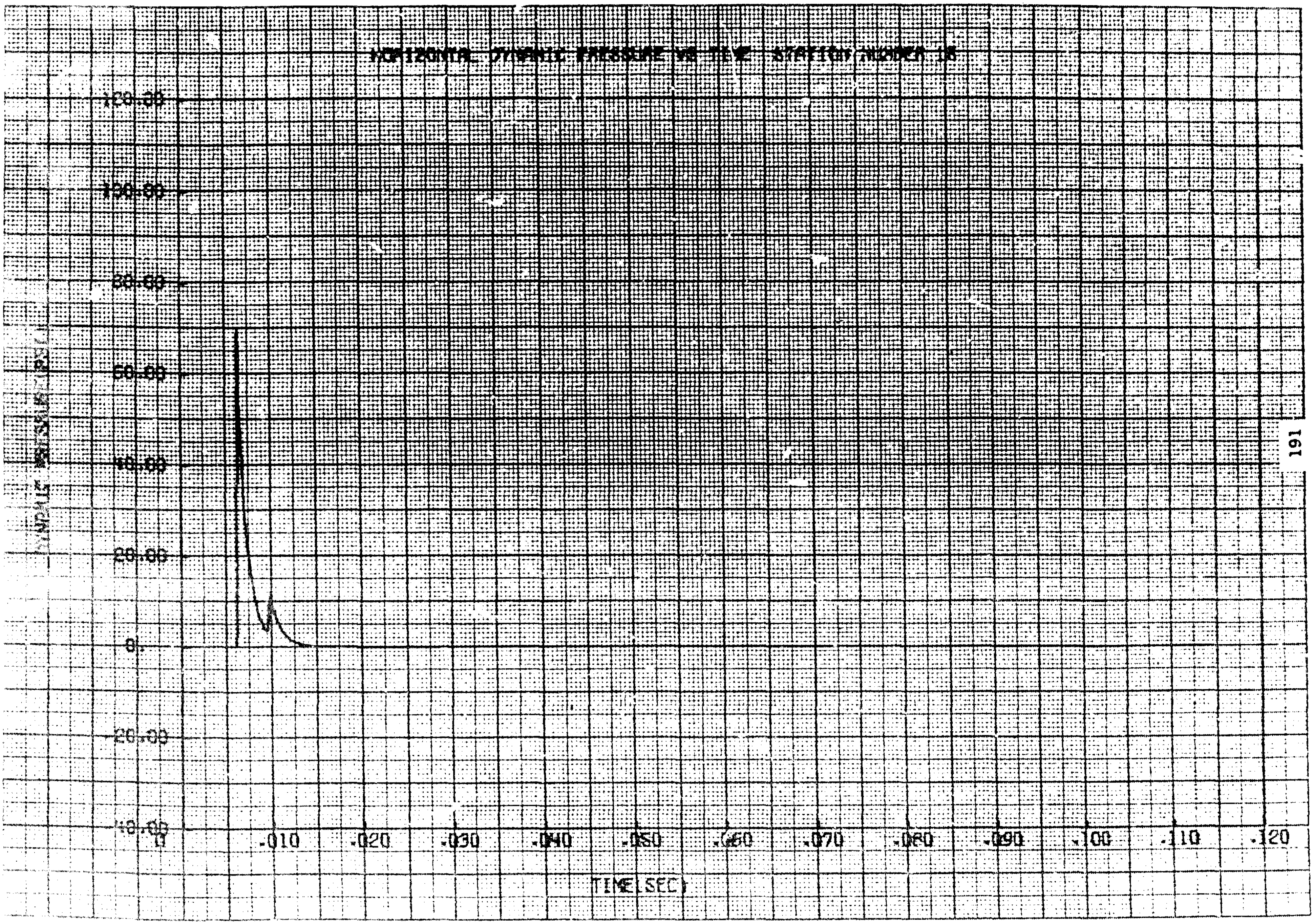

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 1N
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

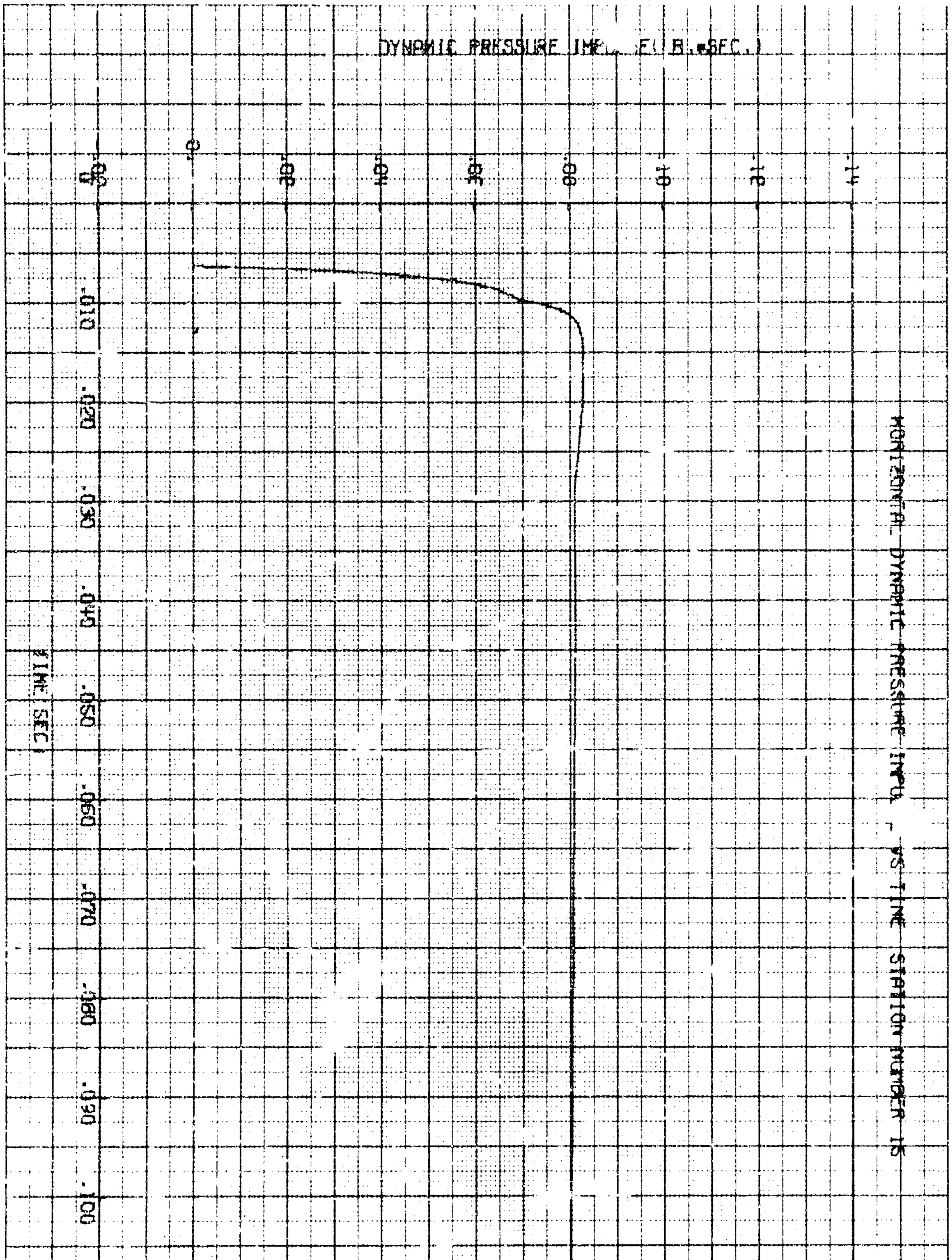

OVER PRESSURE VS TIME STATION NUMBER 18
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.
-10.00
0
.010
.020
.030
.050
.060
.070
.080
.090
.120
TIME(SEC)


OVER PRESSURE IMPULSE VS TIME STATION NUMBER 18
TIME (SEC)
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120

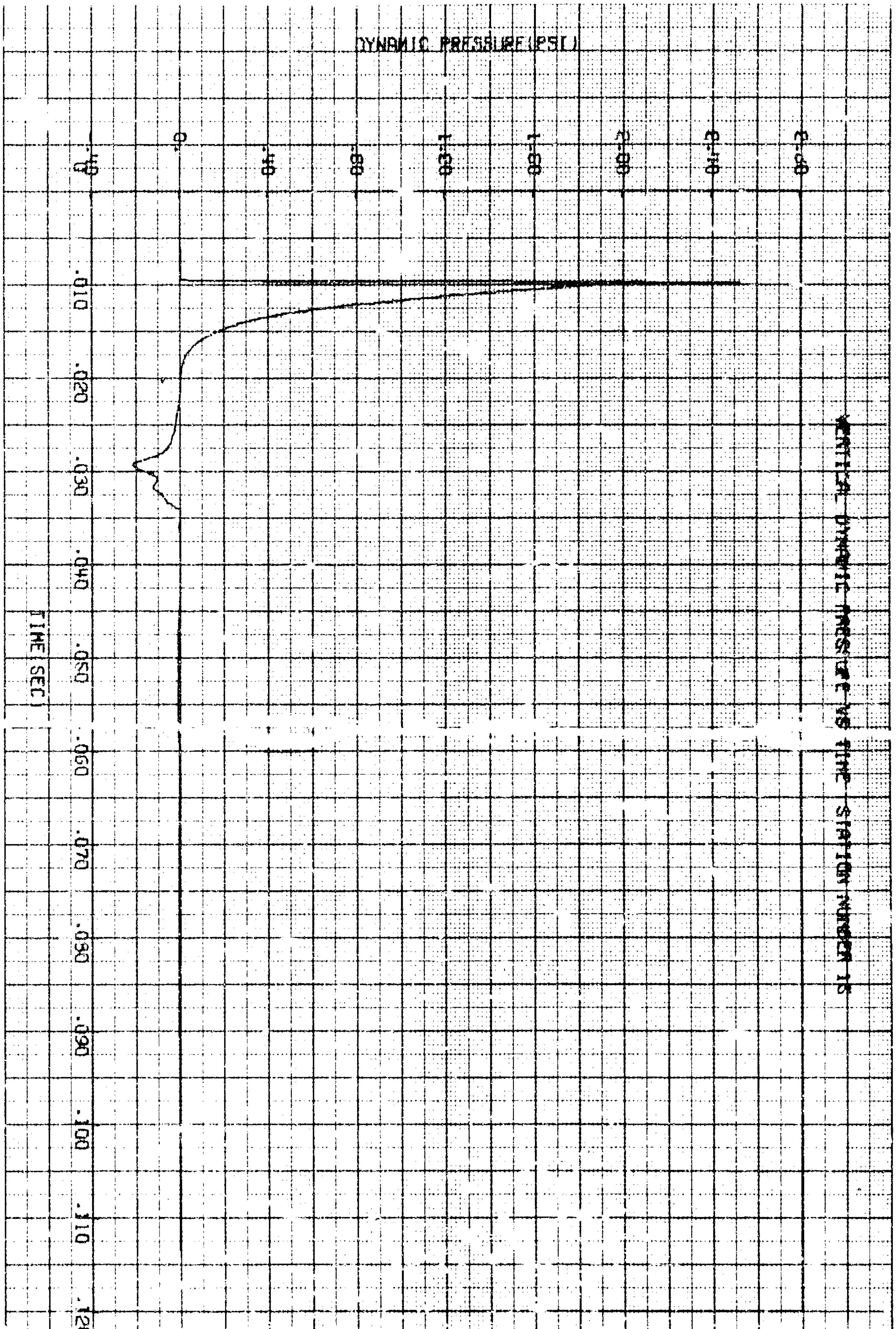

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.
-400.00
-800.00
0
.010
.020
.030
.040
.060
.070
.080
.090
.100
.110
.120
TIME


VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER
0
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

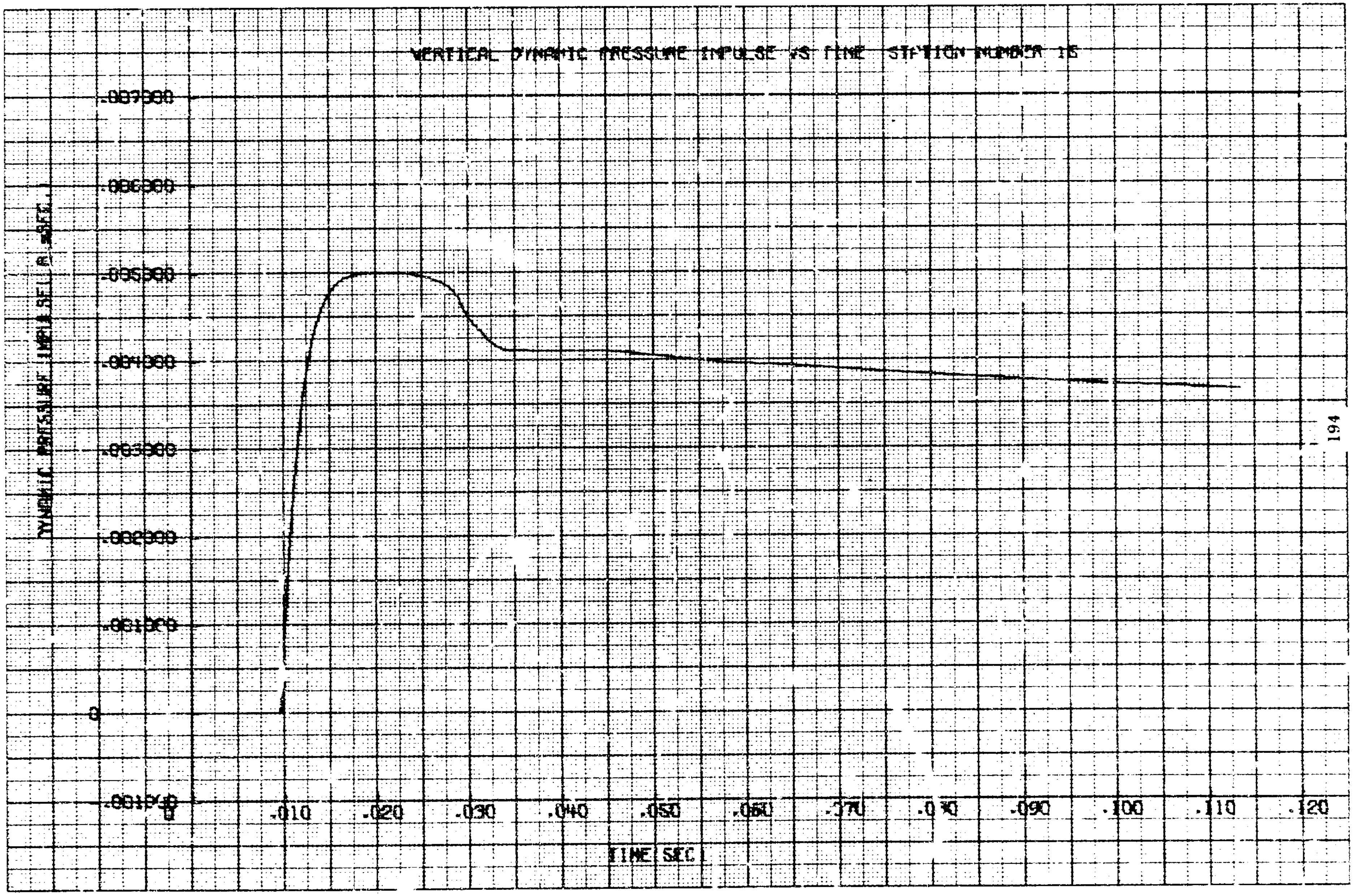

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 16
DYNAMIC PRESSURE (PSI)
120.00
100.00
80.00
60.00
40.00
20.00
0.
-20.00
-40.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

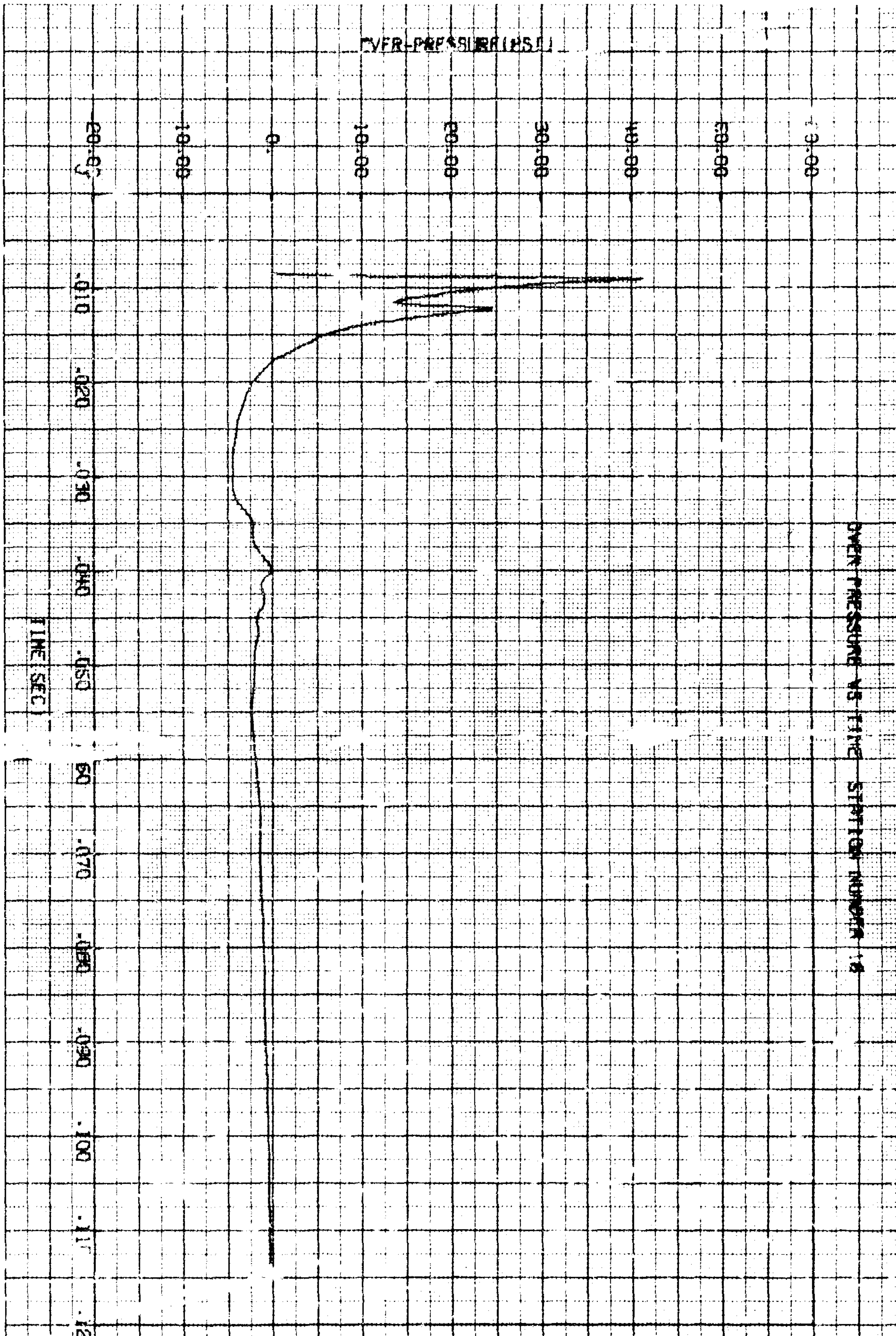


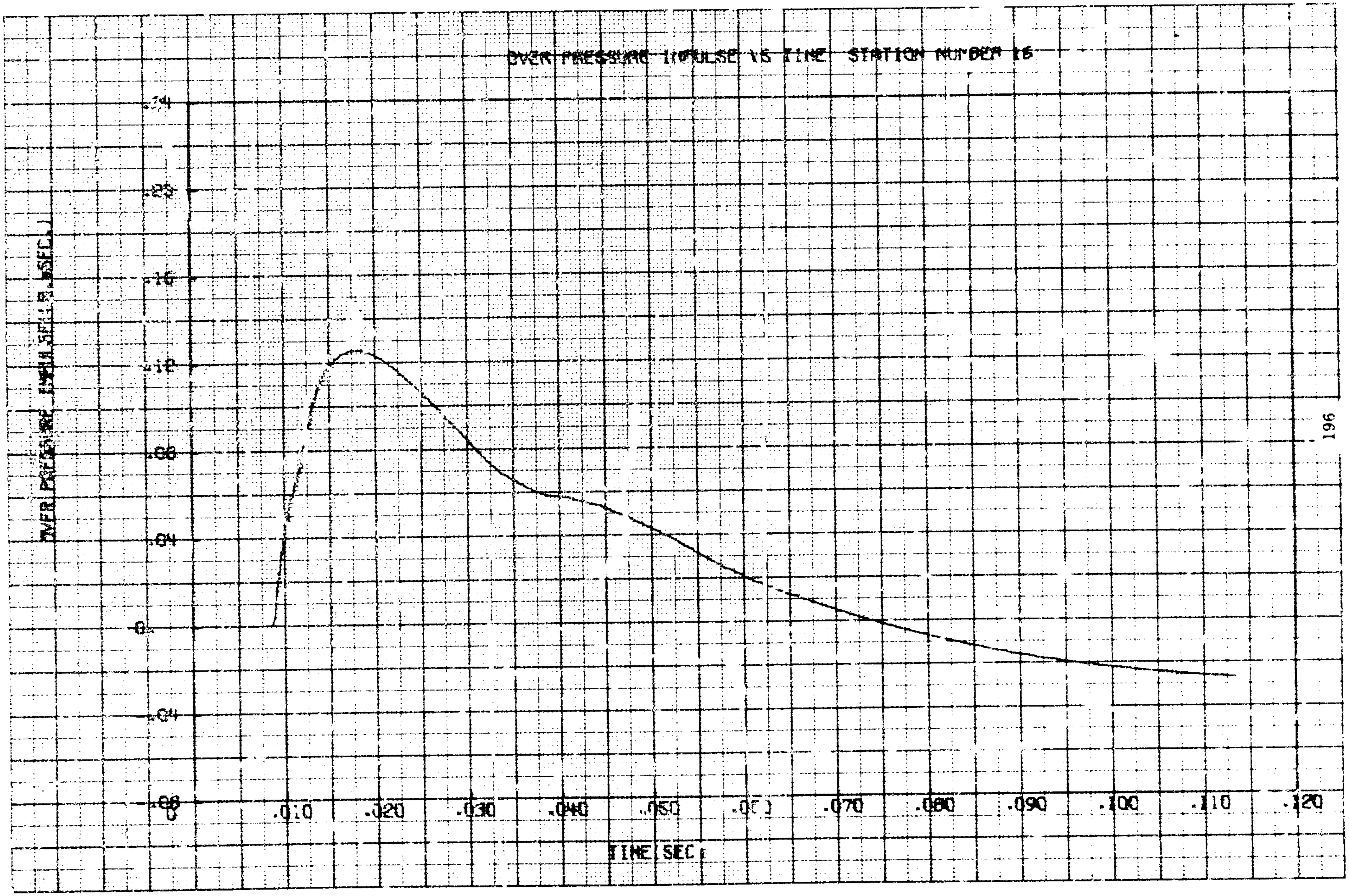
HORIZONTAL DYNAMIC PRESSURE IMPU... VS TIME STATION NUMBER 15
TIME SEC
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120



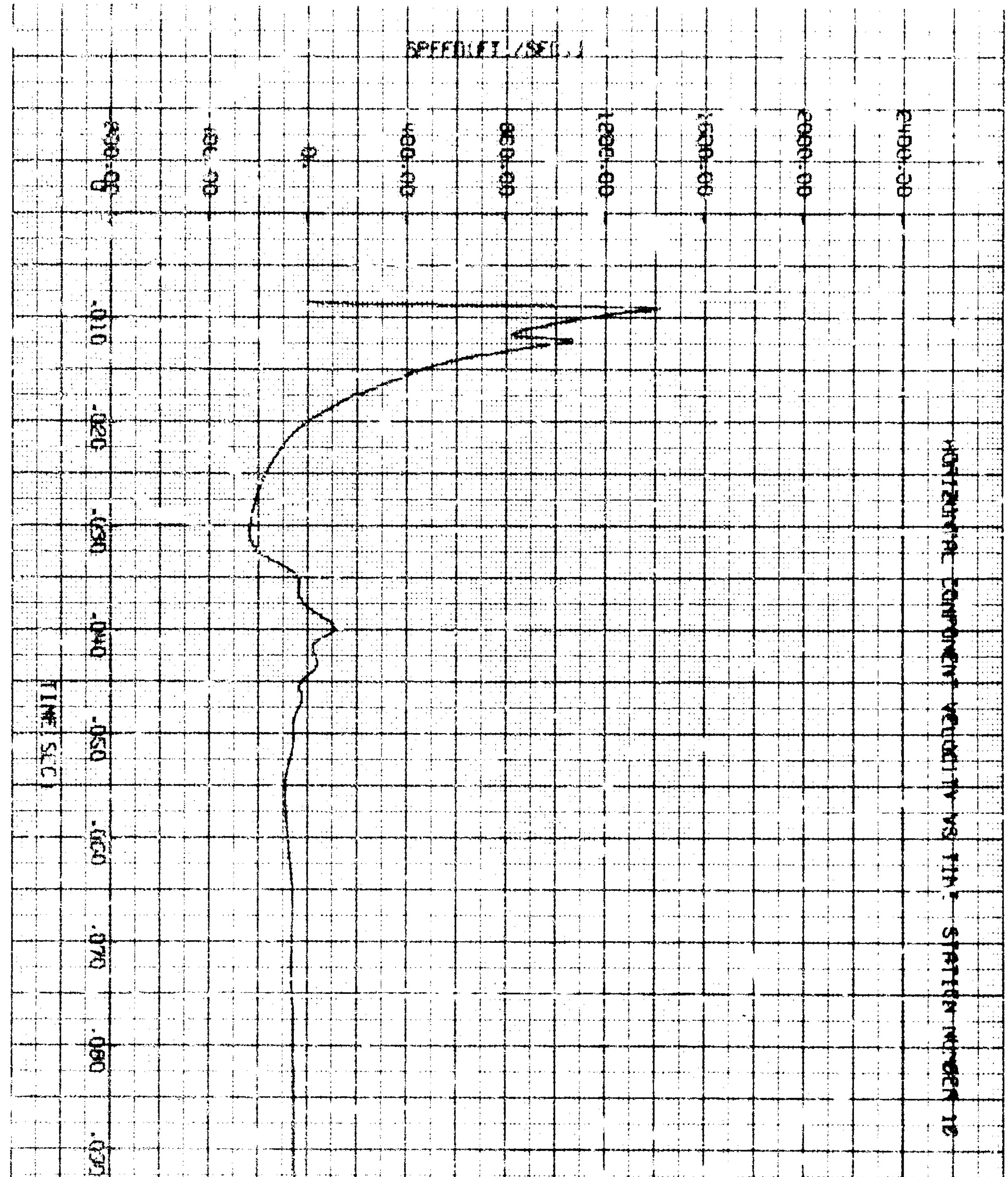
DYNAMIC PRESSURE(PSI)
-0.40
0
.40
.80
1.20
1.60
2.00
2.40
2.80
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)
VERTICAL DYNAMIC PRESSURE VS TIME STATION NUMBER 15

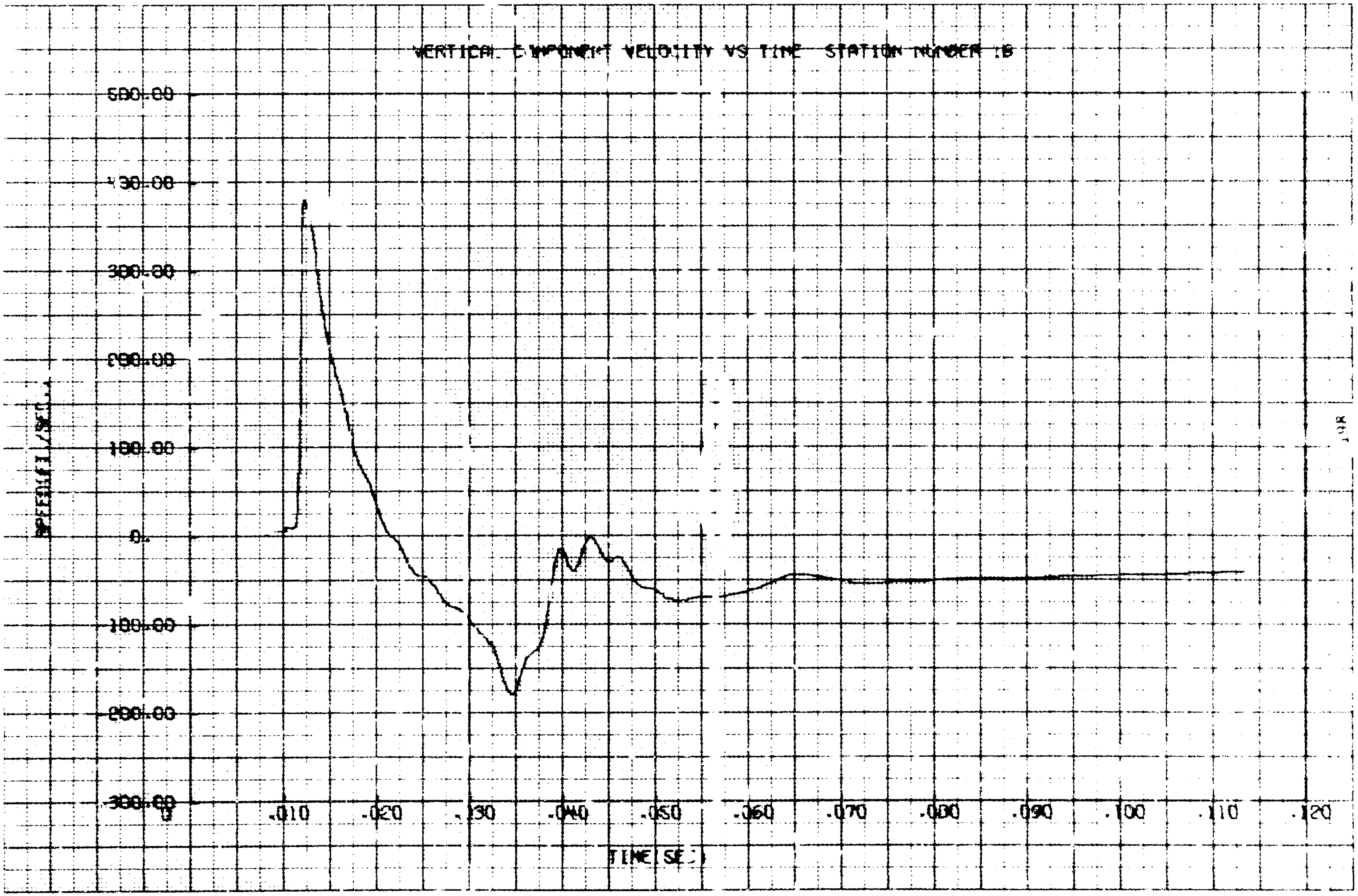

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 15
.007000
.006000
.005000
.004000
.003000
.002000
.001000
0
-.001000
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC


OVER-PRESSURE (PSI)
10.00
0.
10.00
20.00
30.00
40.00
50.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)
OVER PRESSURE VS TIME STATION NUMBER 18

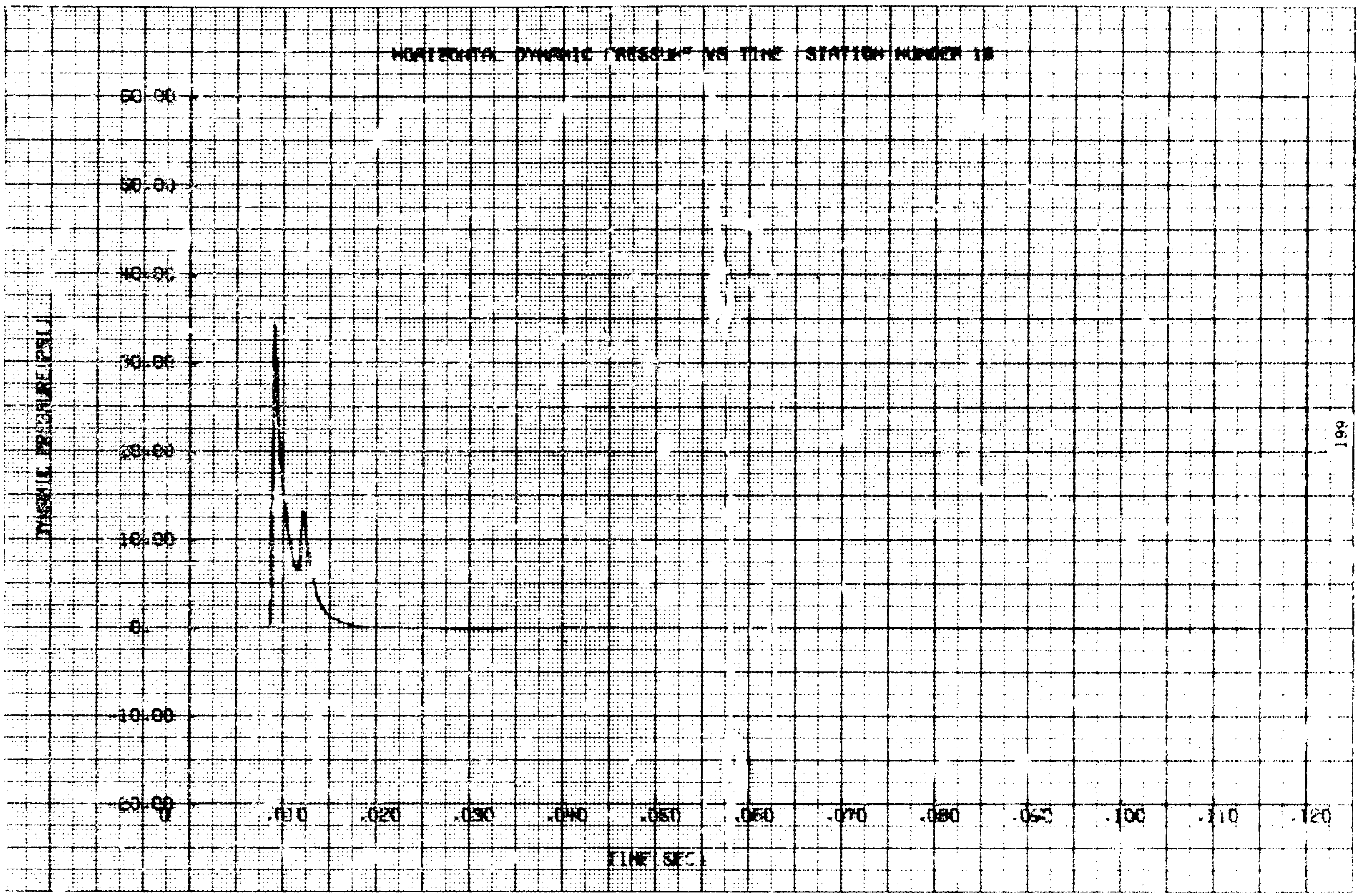


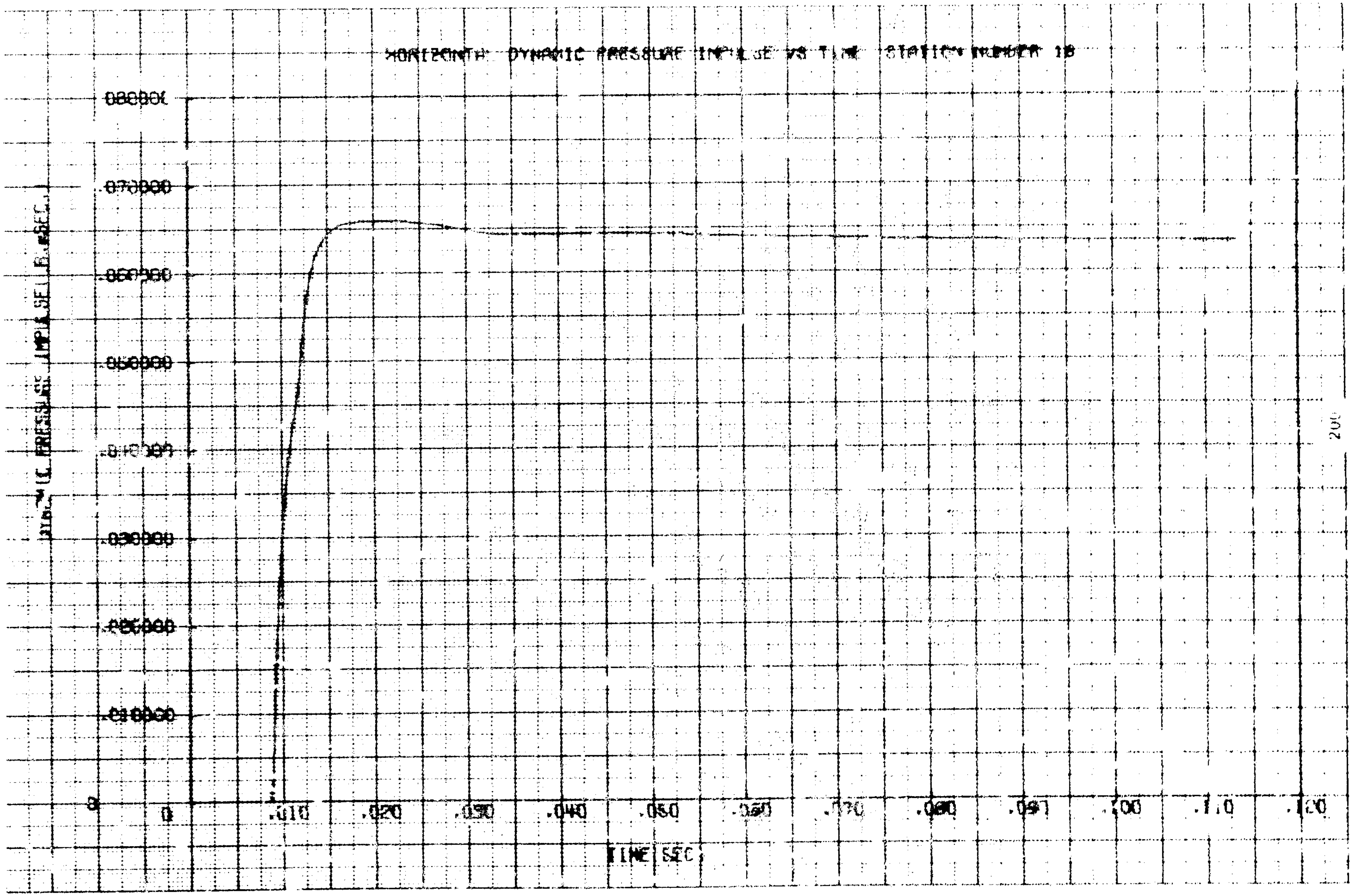
OVER PRESSURE IMPULSE VS TIME STATION NUMBER 16
.24
.20
.16
.12
.08
.04
0
-.04
-.08
0
.010
.020
.030
.040
.050
.070
.080
.090
.100
.110
.120
TIME SEC

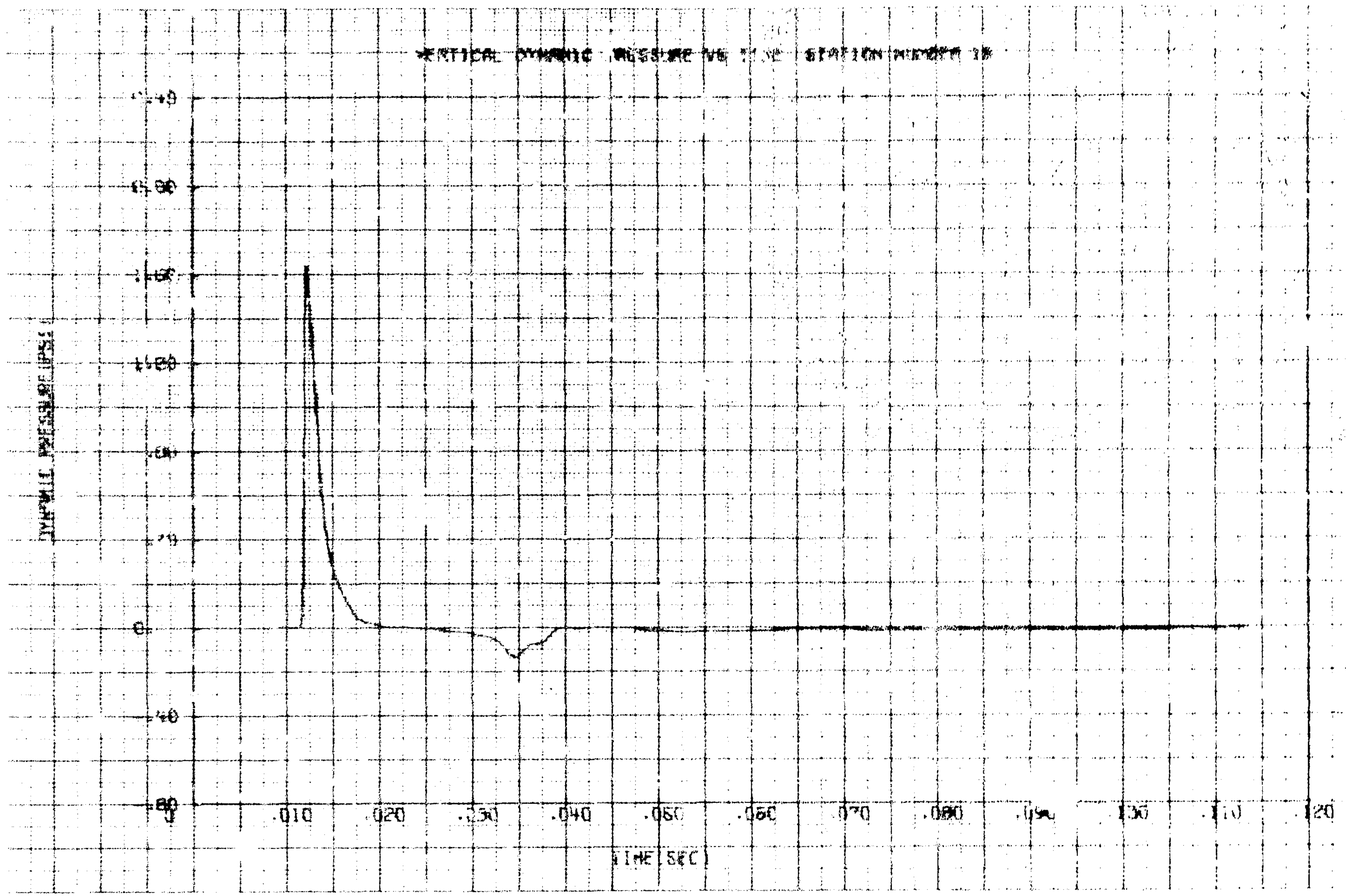

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER
SPEED(FT./SEC.)
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC)

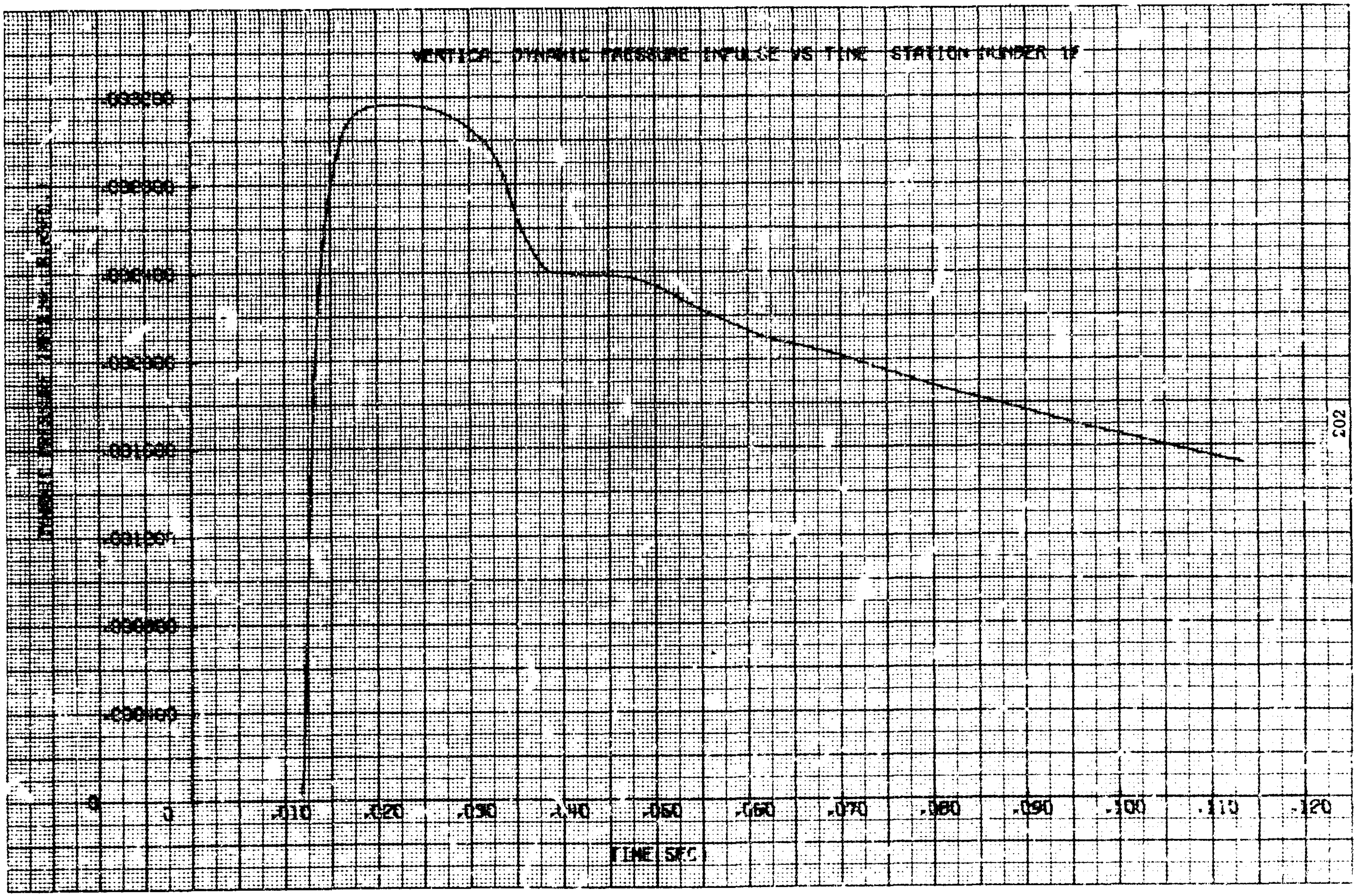


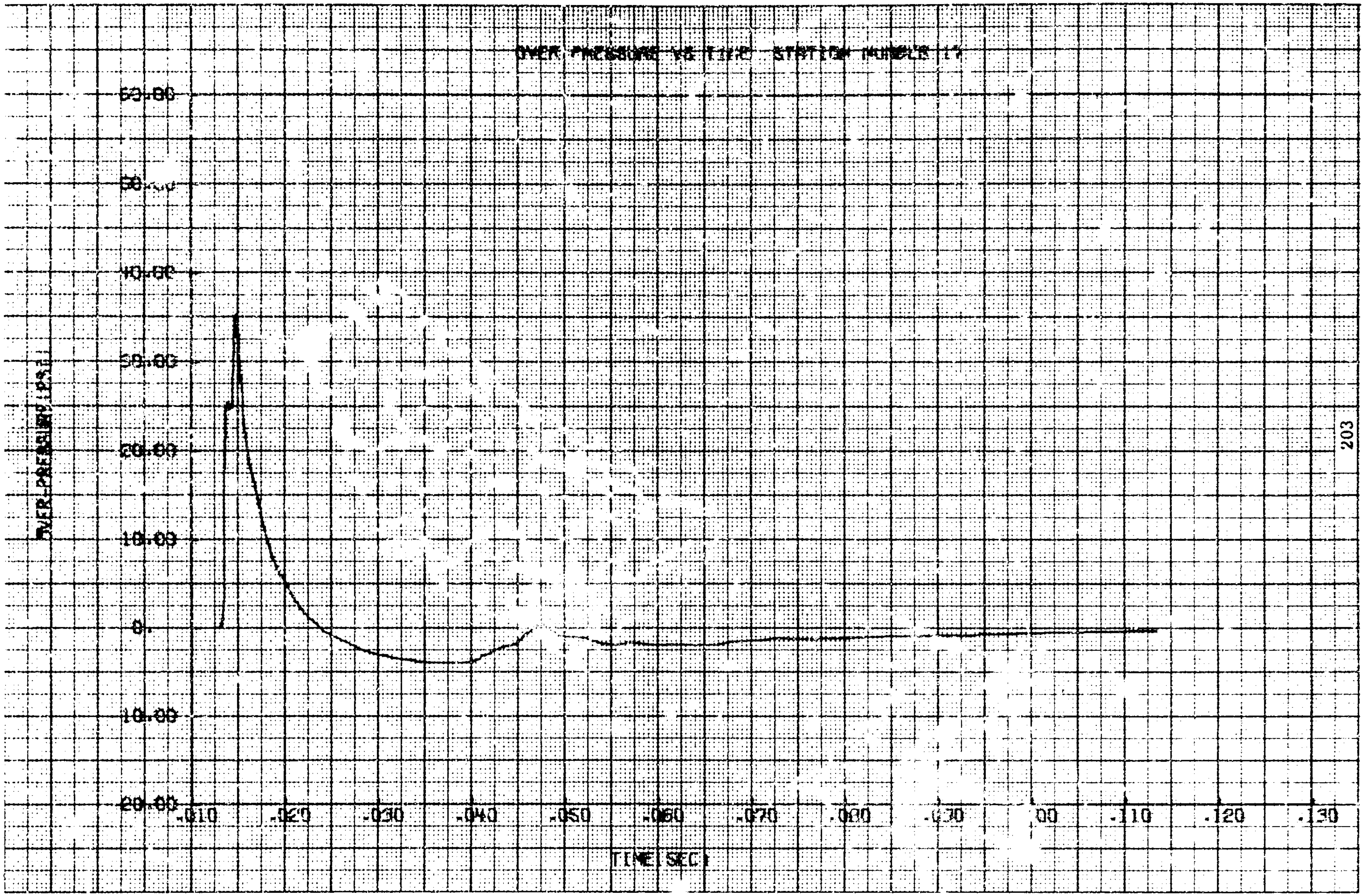
VERTICAL COMPONENT VELOCITY VS TIME STATION NUMBER
SPEED(FT./SEC.)
500.00
300.00
100.00
0.
-100.00
-200.00
-300.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME(SEC.)

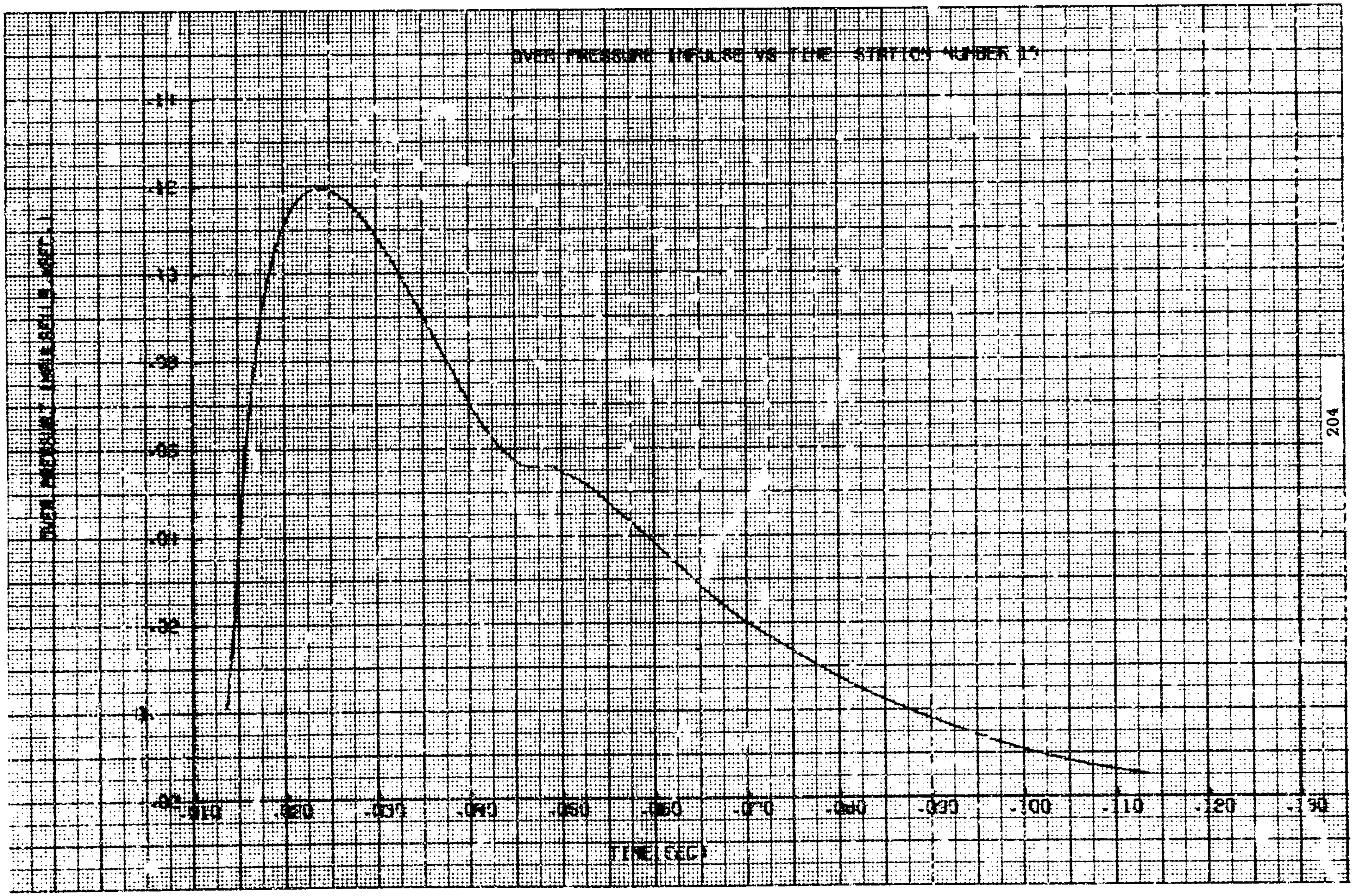

DYNAMIC PRESSURE(PSI)
60.00
50.00
40.00
30.00
20.00
10.00
0
-10.00
-20.00
0
.010
.020
.030
.040
.050
.060
.070
.080
.100
.110
.120
TIME(SEC)

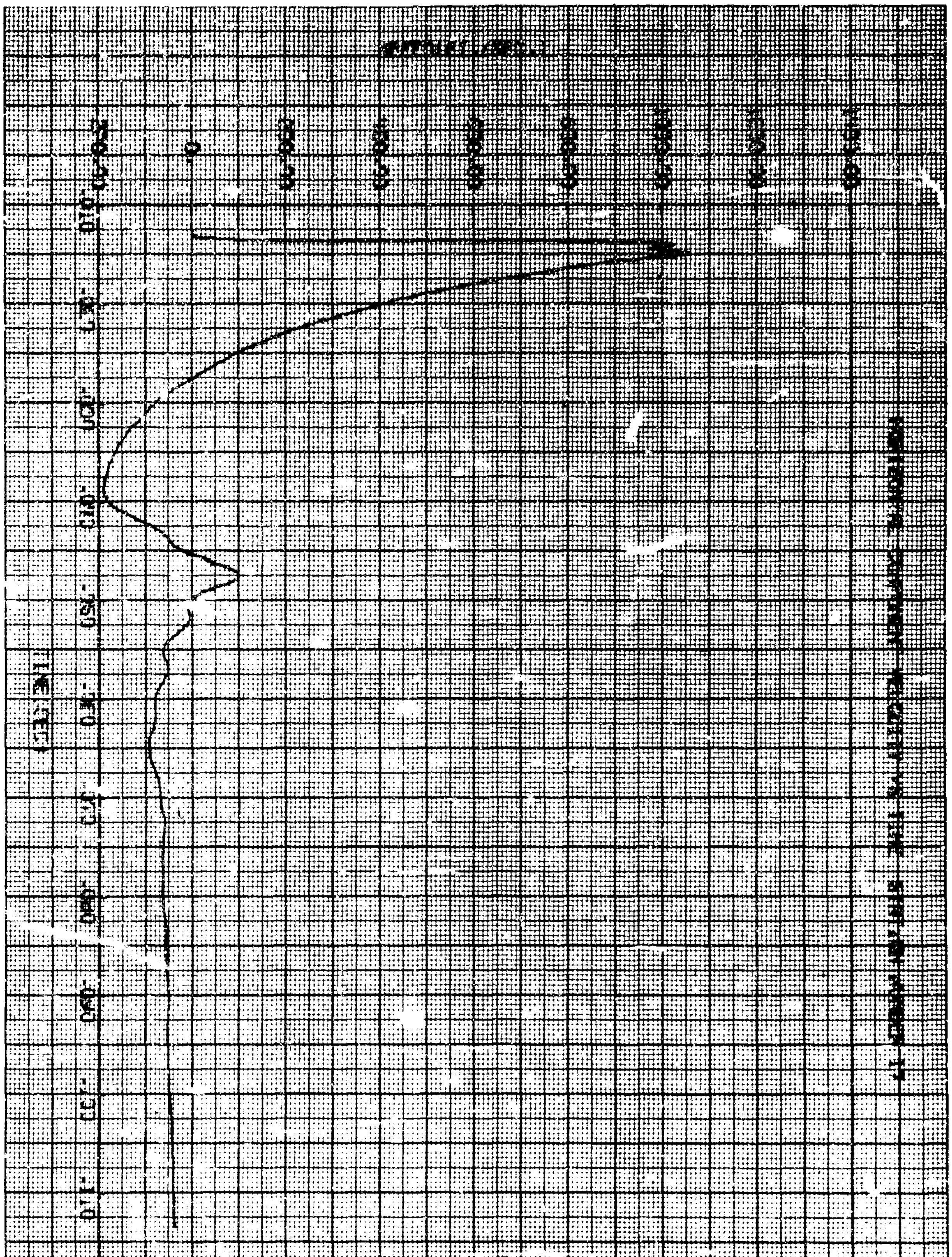

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 18
.080000
.070000
.060000
.050000
.040000
.030000
.020000
.010000
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME (SEC)

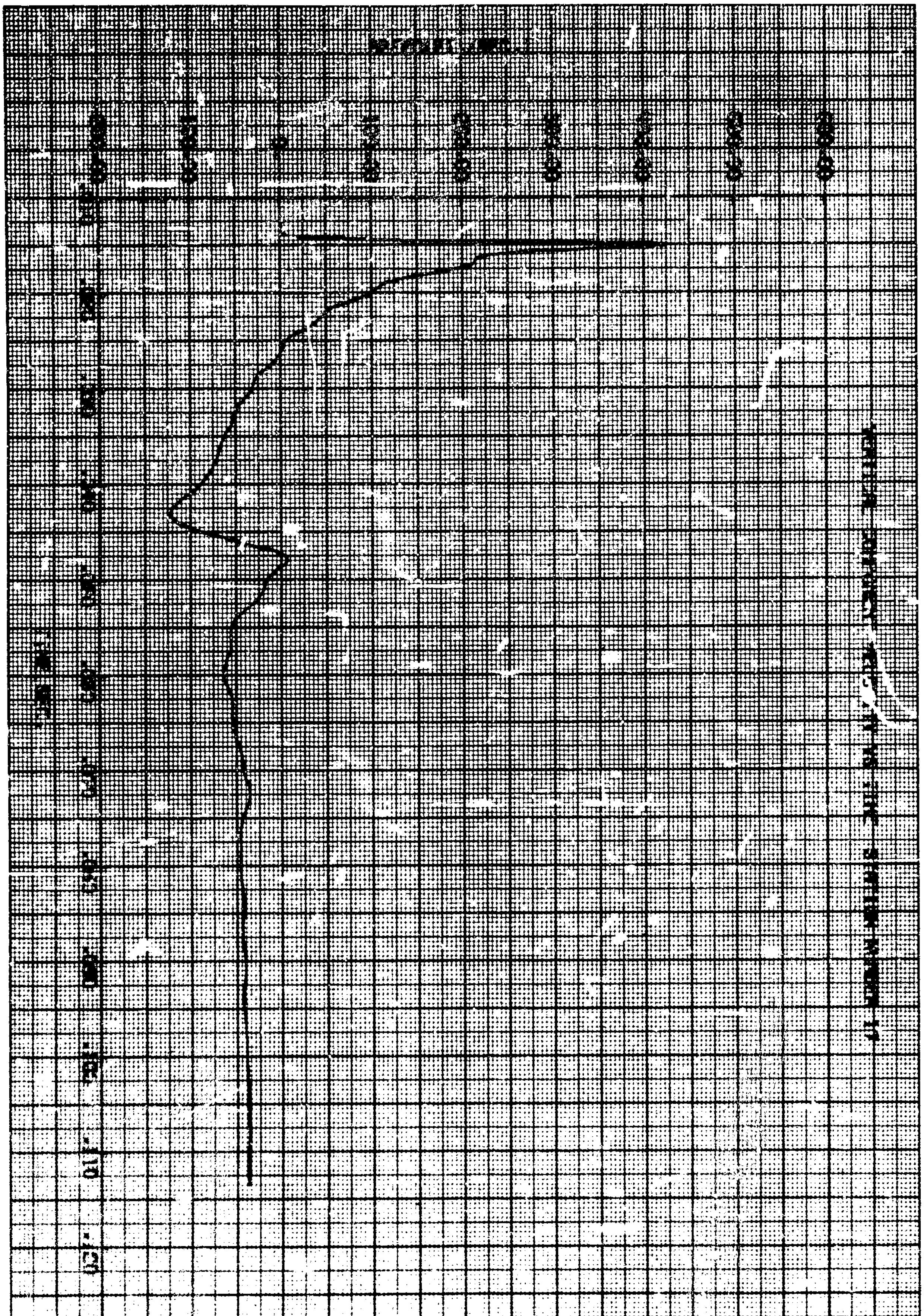

DYNAMIC PRESSURE (PSI)
0
.010
.020
.040
.120
TIME (SEC)

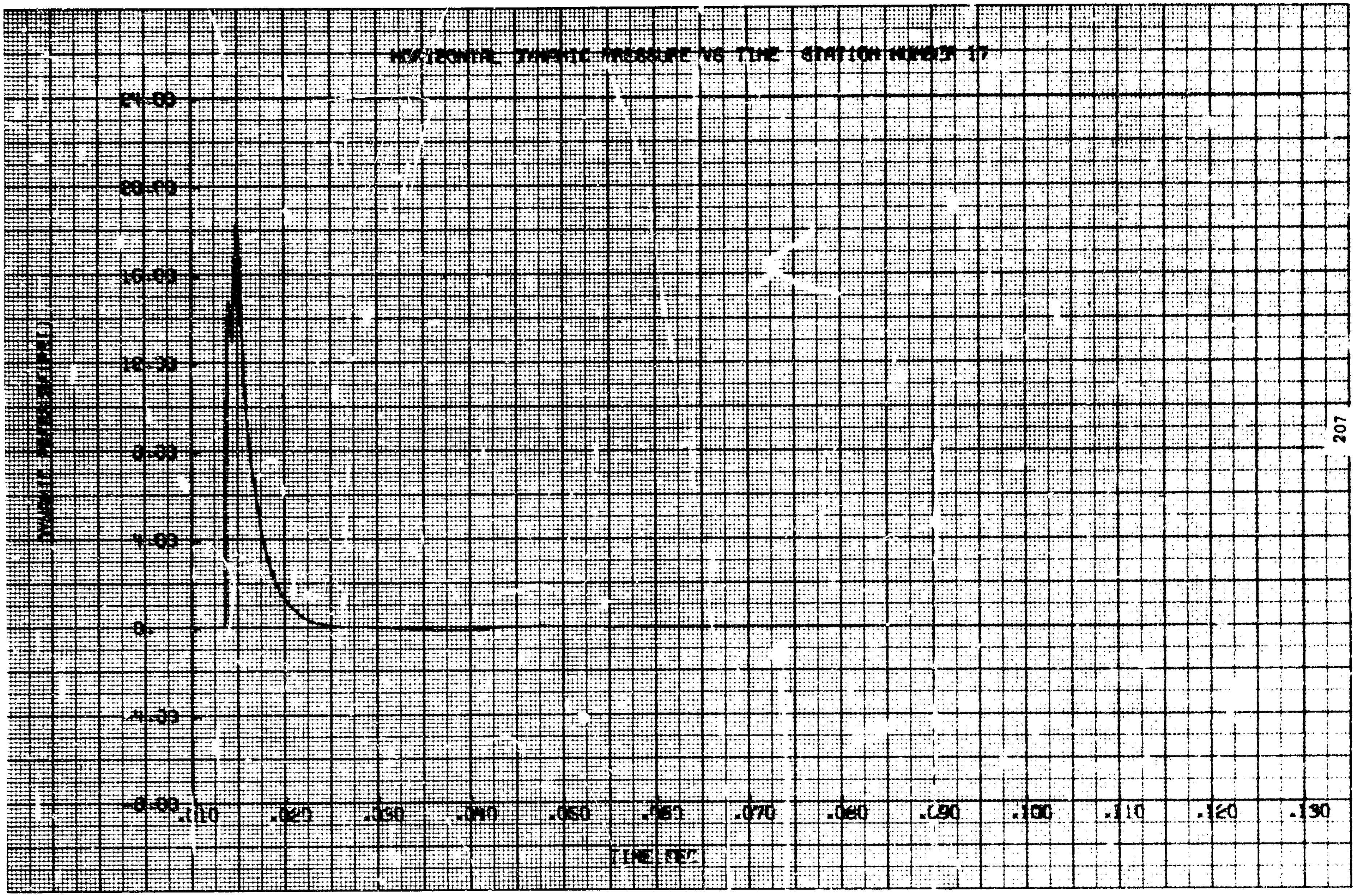

VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
TIME SEC

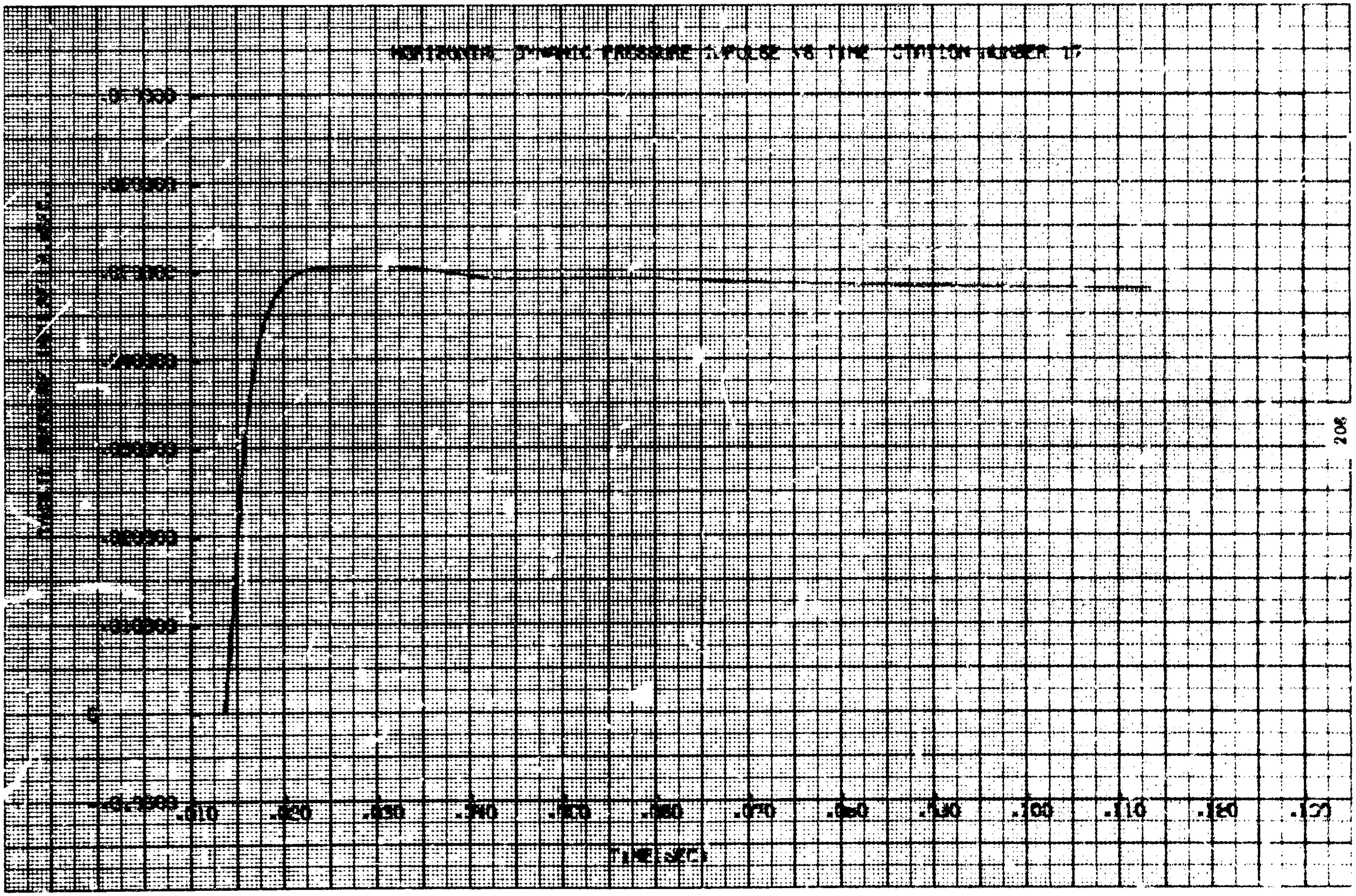

OVER PRESSURE VS TIME STATION NUMBER 17
OVER-PRESSURE (PSI)
TIME (SEC)
10.00
0.
-10.00
-20.00
.010
.020
.030
.040
.050
.060
.070
.080
.110
.120
.130

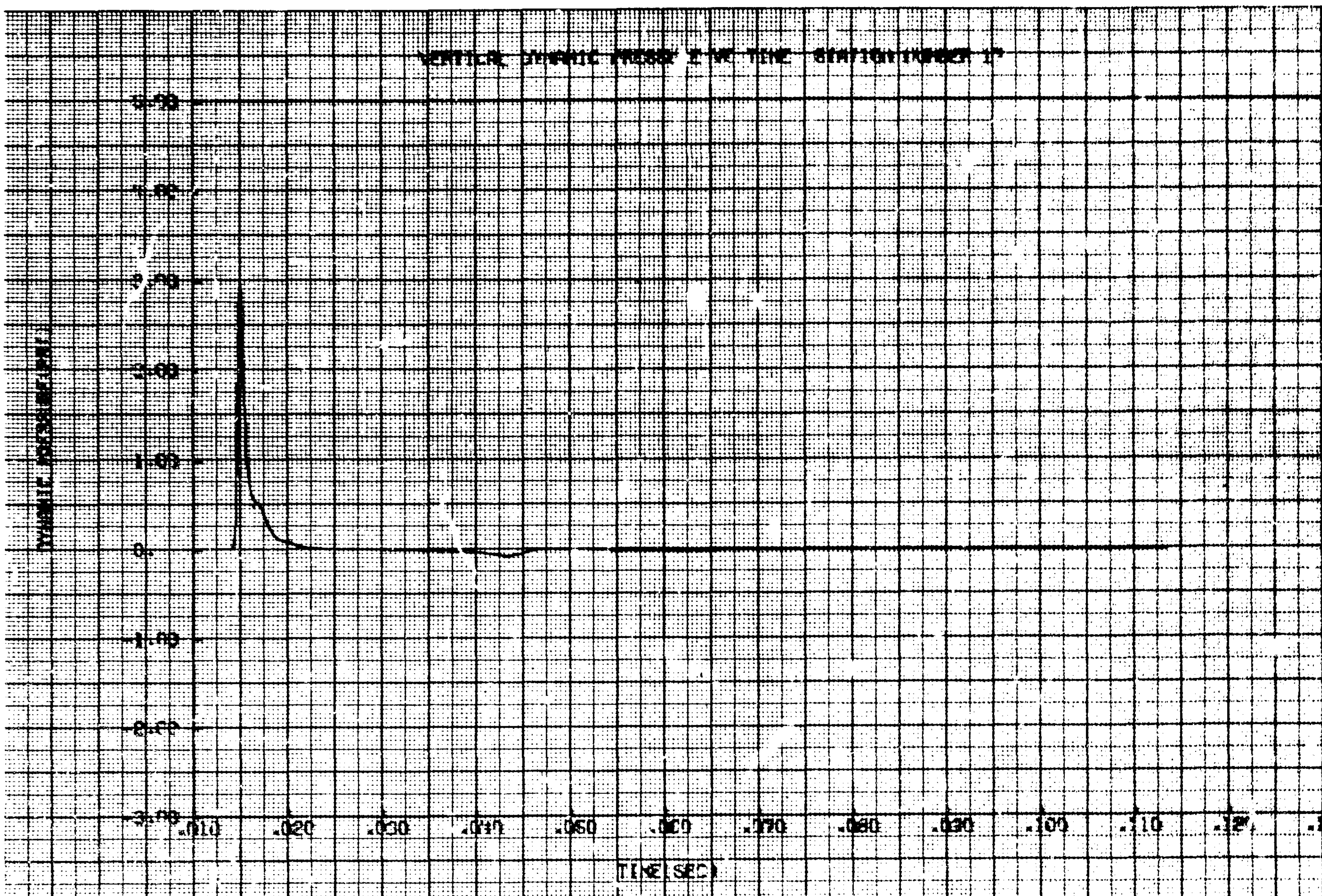

OVER PRESSURE IMPULSE VS TIME STATION NUMBER
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME (SEC)

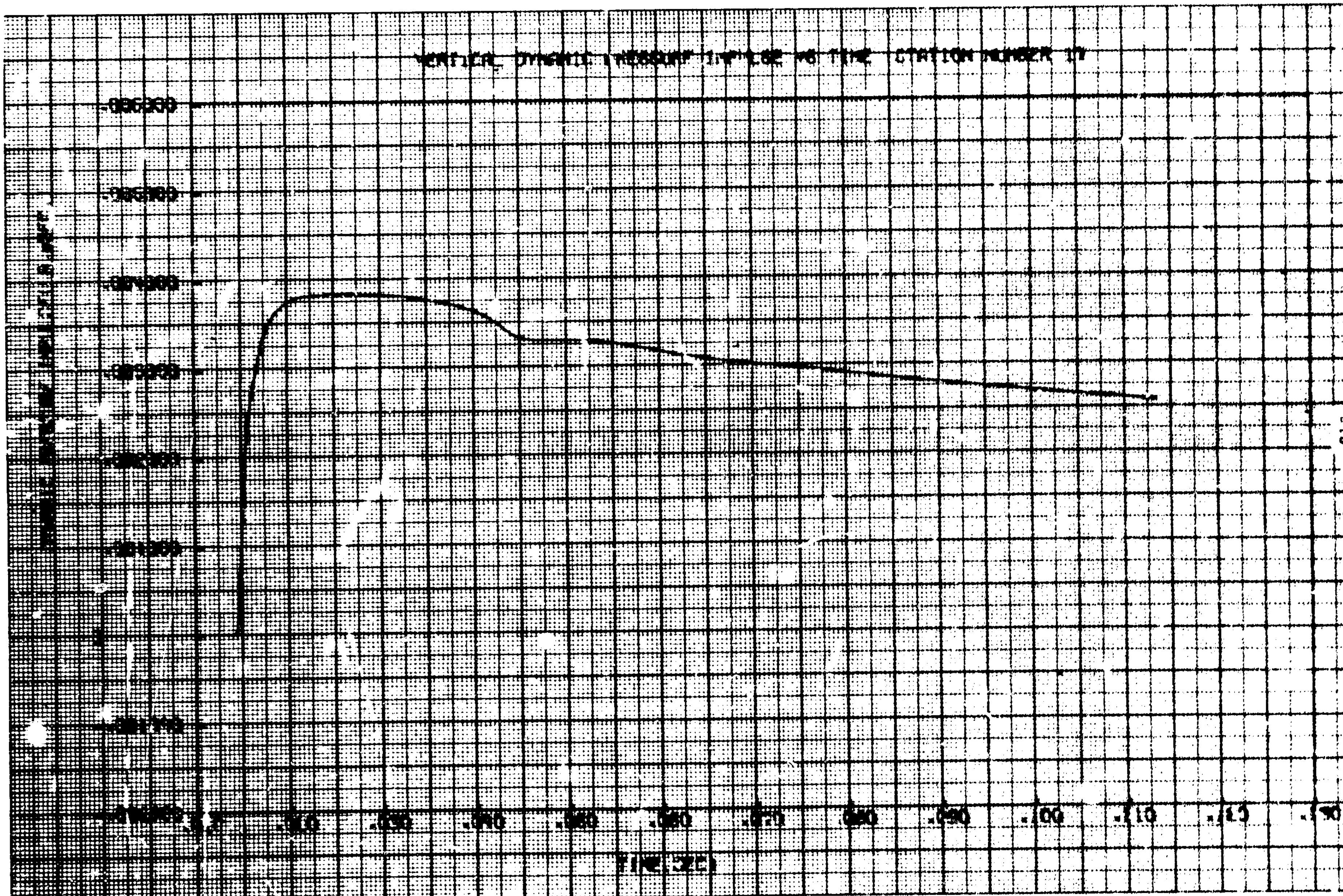

HORIZONTAL COMPONENT VELOCITY VS TIME STATION NUMBER 17
TIME (SEC)

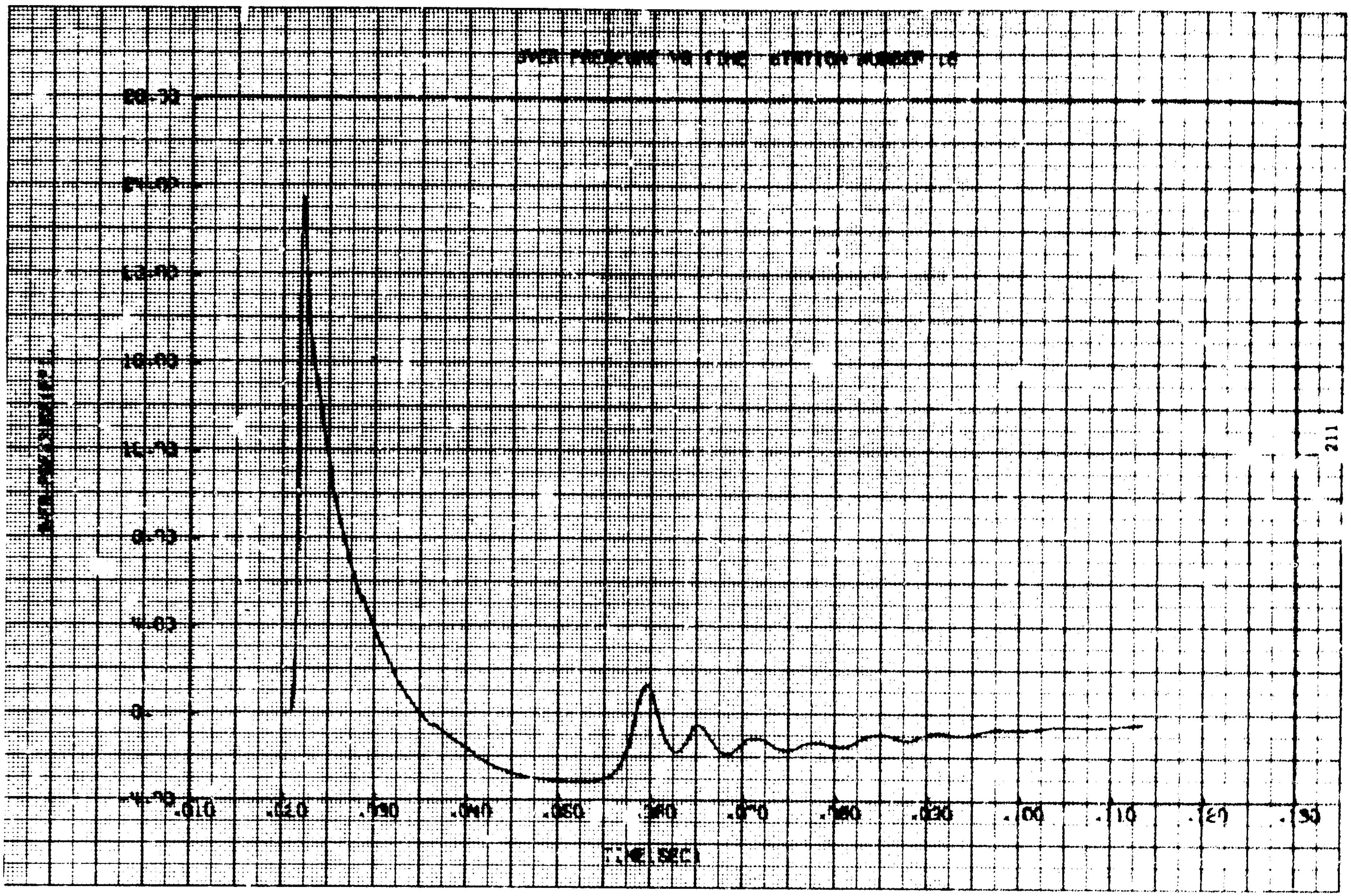


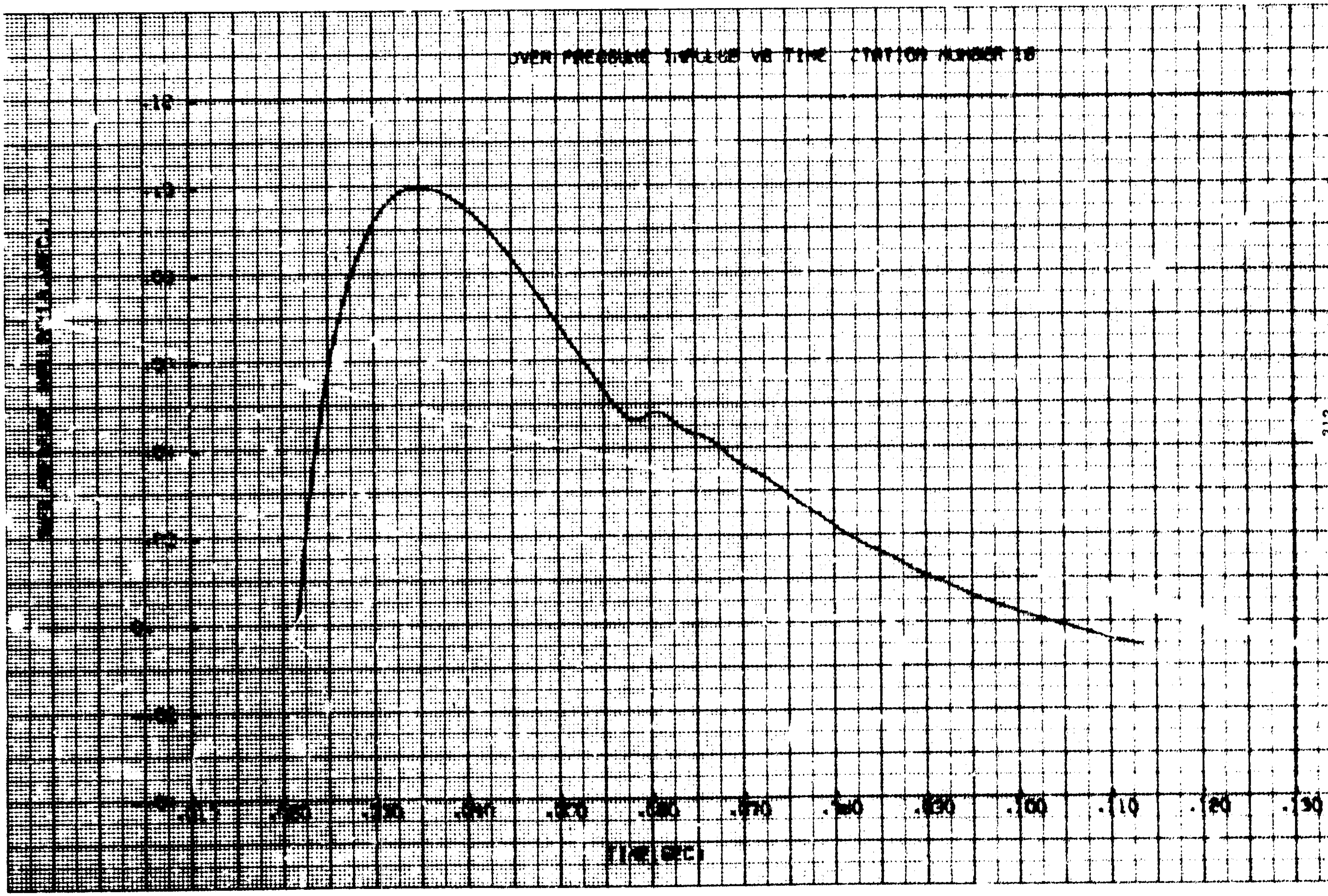

HORIZONTAL DYNAMIC PRESSURE VS TIME STATION NUMBER 17
DYNAMIC PRESSURE(PSI)
24.00
20.00
16.00
12.00
8.00
4.00
0.
-4.00
-8.00
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
.120
.130
TIME SEC

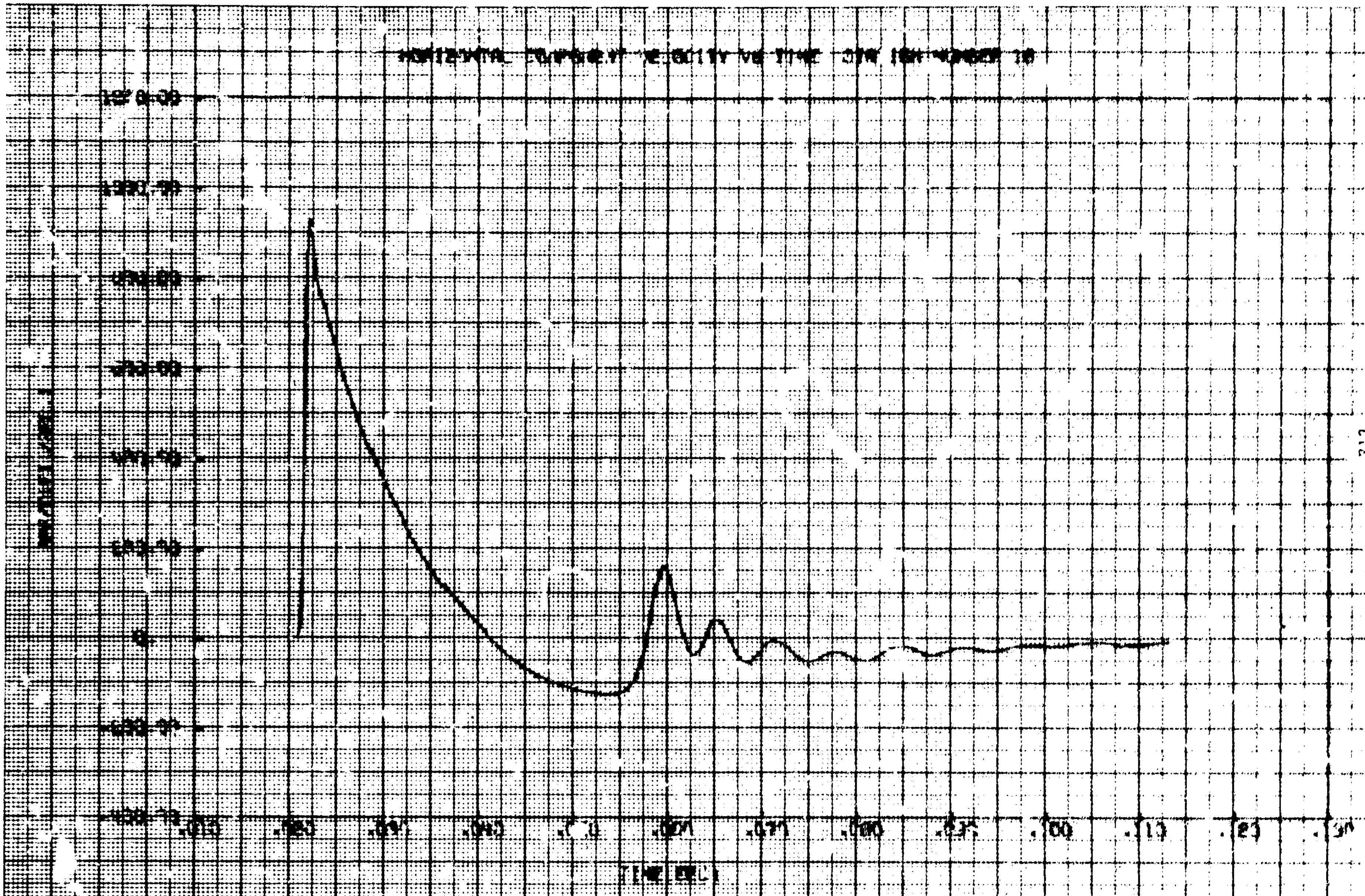

HORIZONTAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 17
0
.010
.020
.030
.040
.050
.060
.070
.080
.090
.100
.110
TIME SEC


TIME SEC
0.
1.00
-1.00
.020
.030
.100
.110


VERTICAL DYNAMIC PRESSURE IMPULSE VS TIME STATION NUMBER 17
TIME (SEC)


.010
.020
.100
.110
.120
.130
TIME(SEC)


OVER PRESSURE IMPULSE VS TIME STATION NUMBER 10
TIME (SEC)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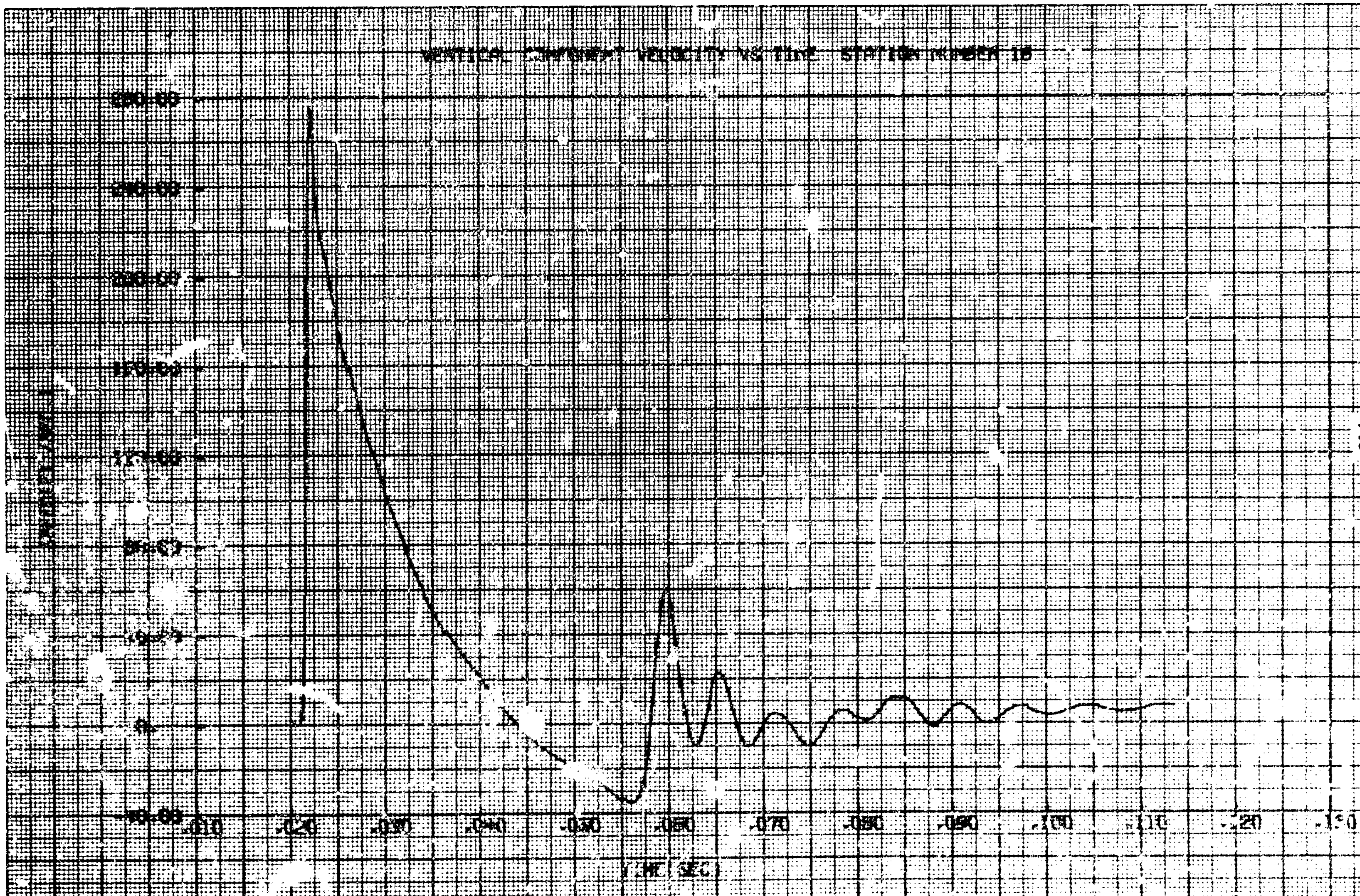
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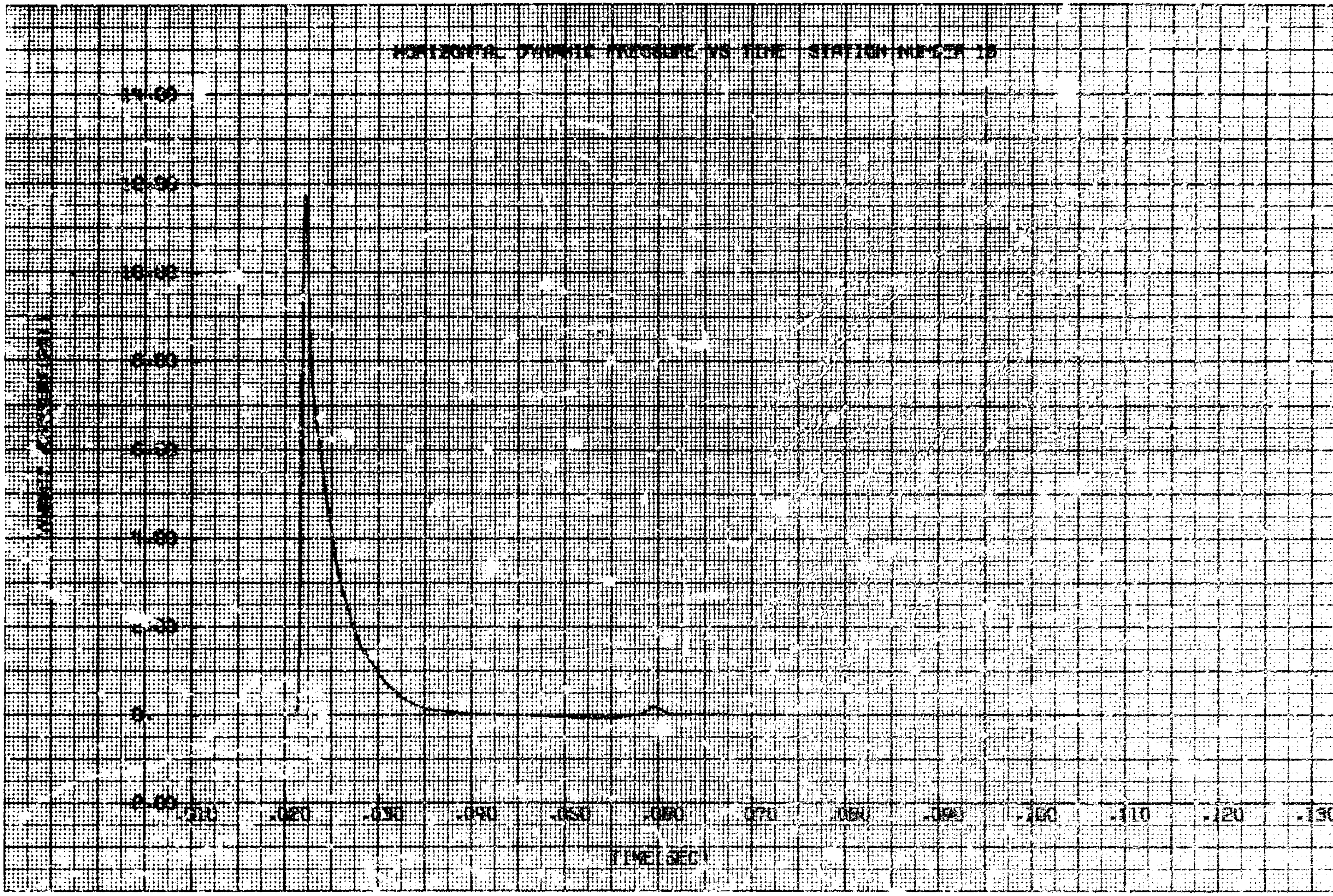
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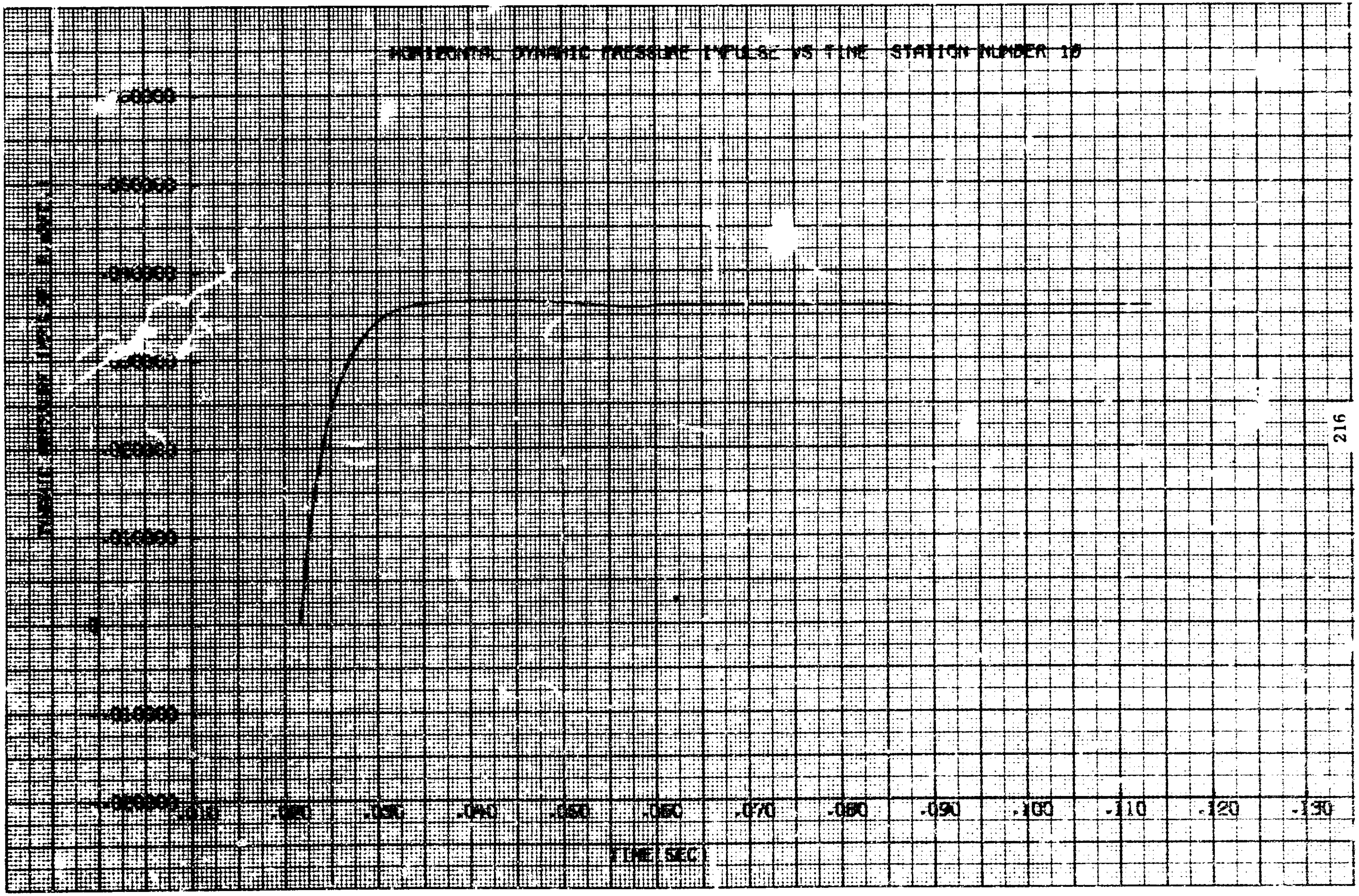

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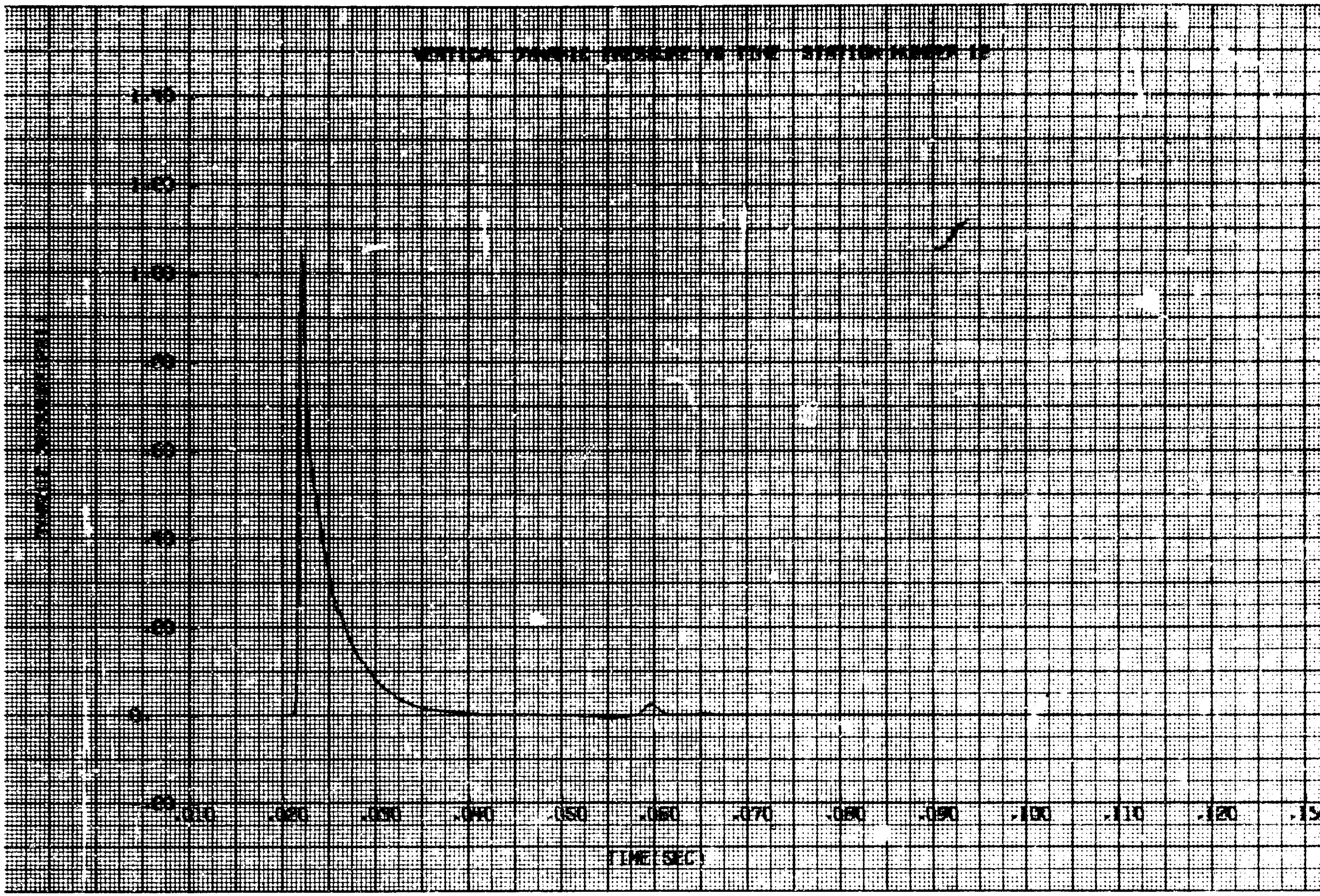

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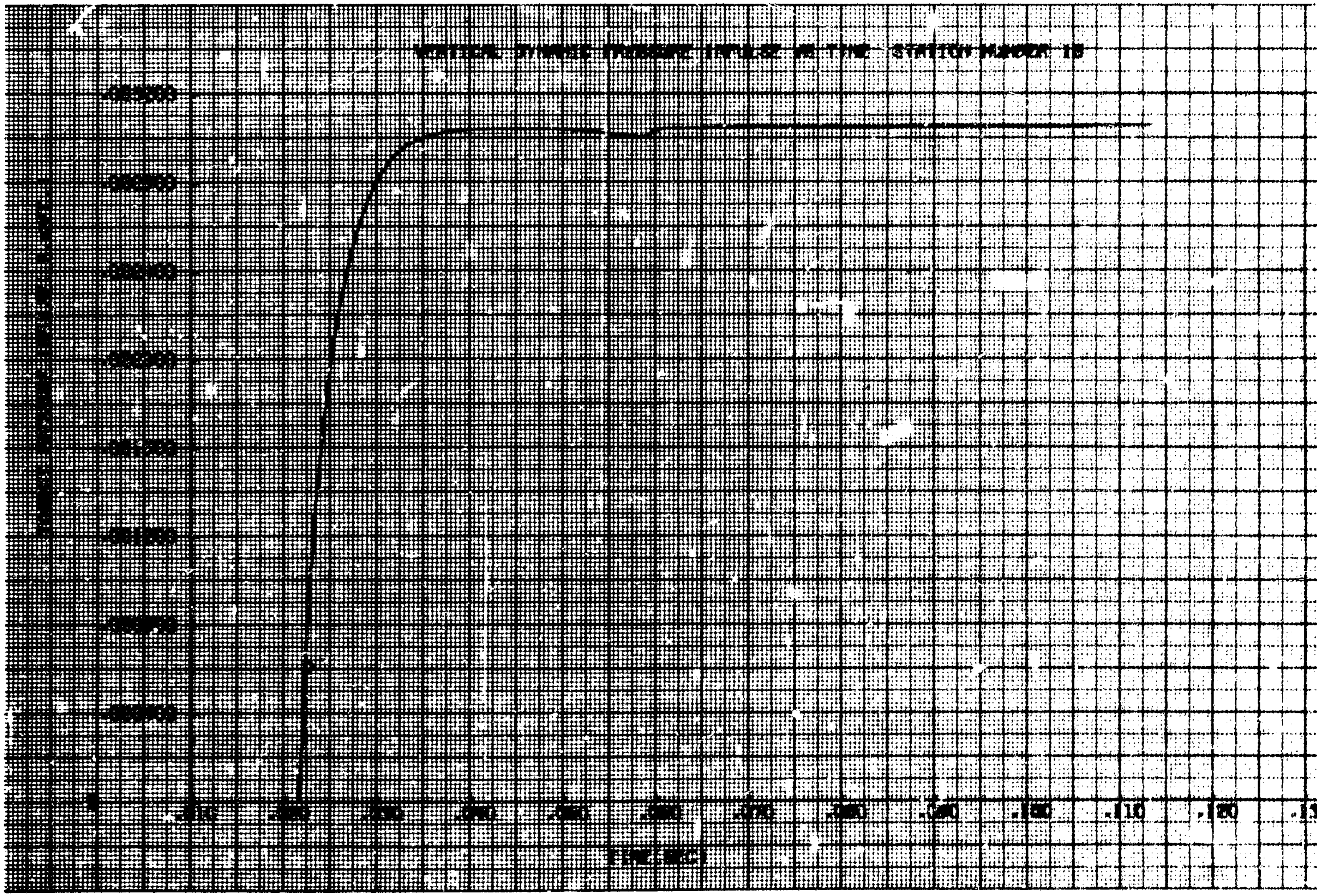
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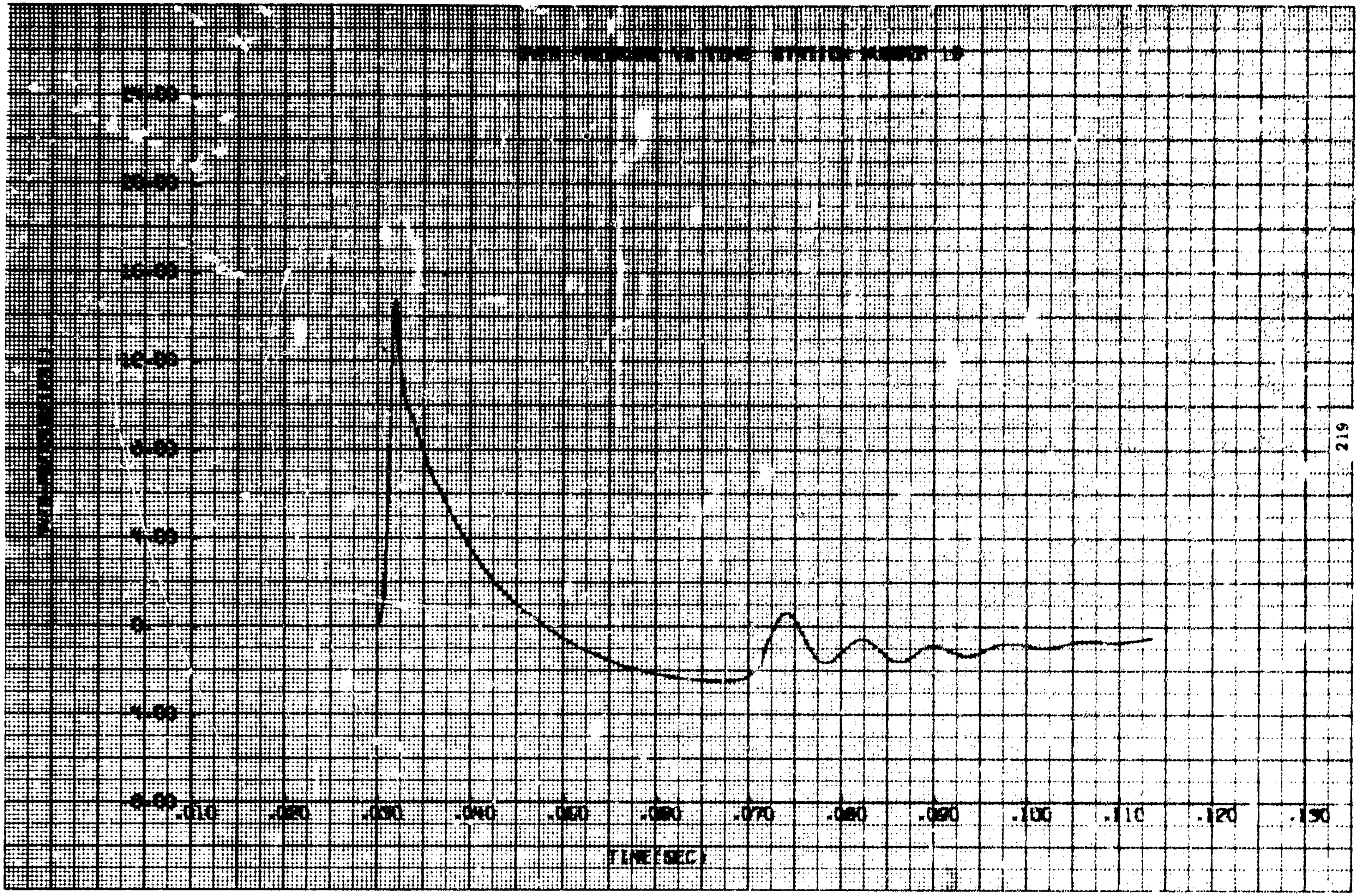
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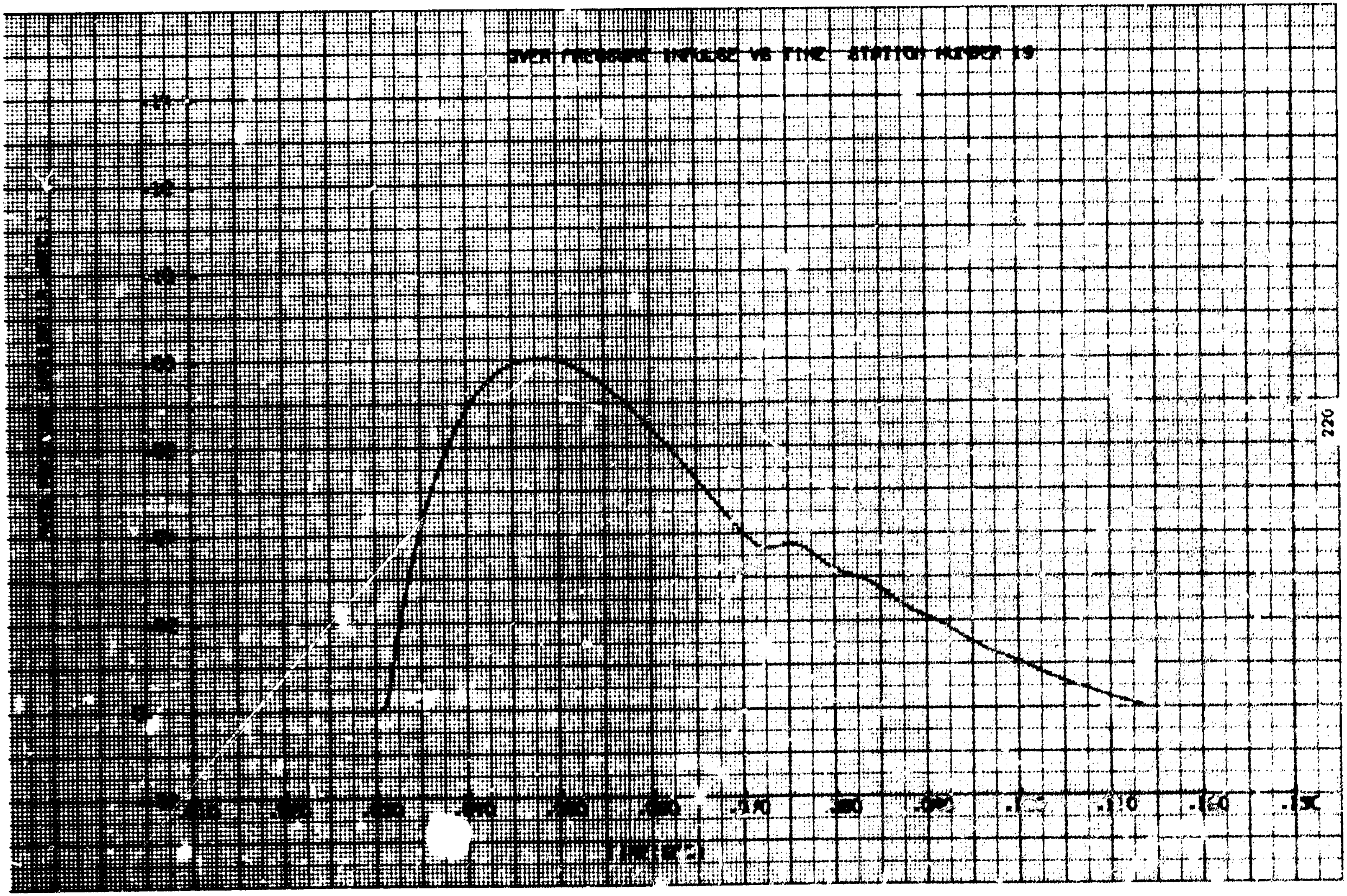
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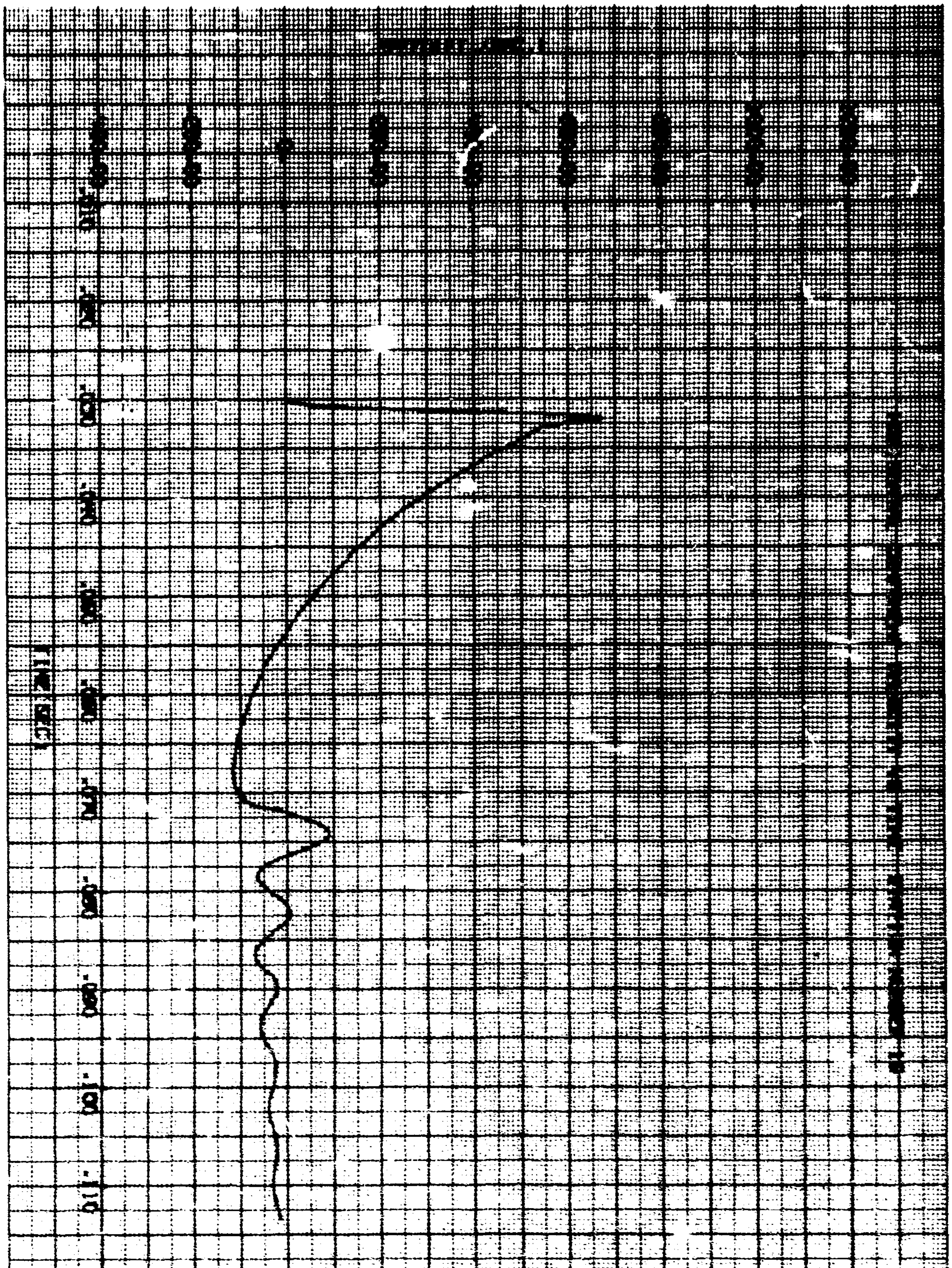

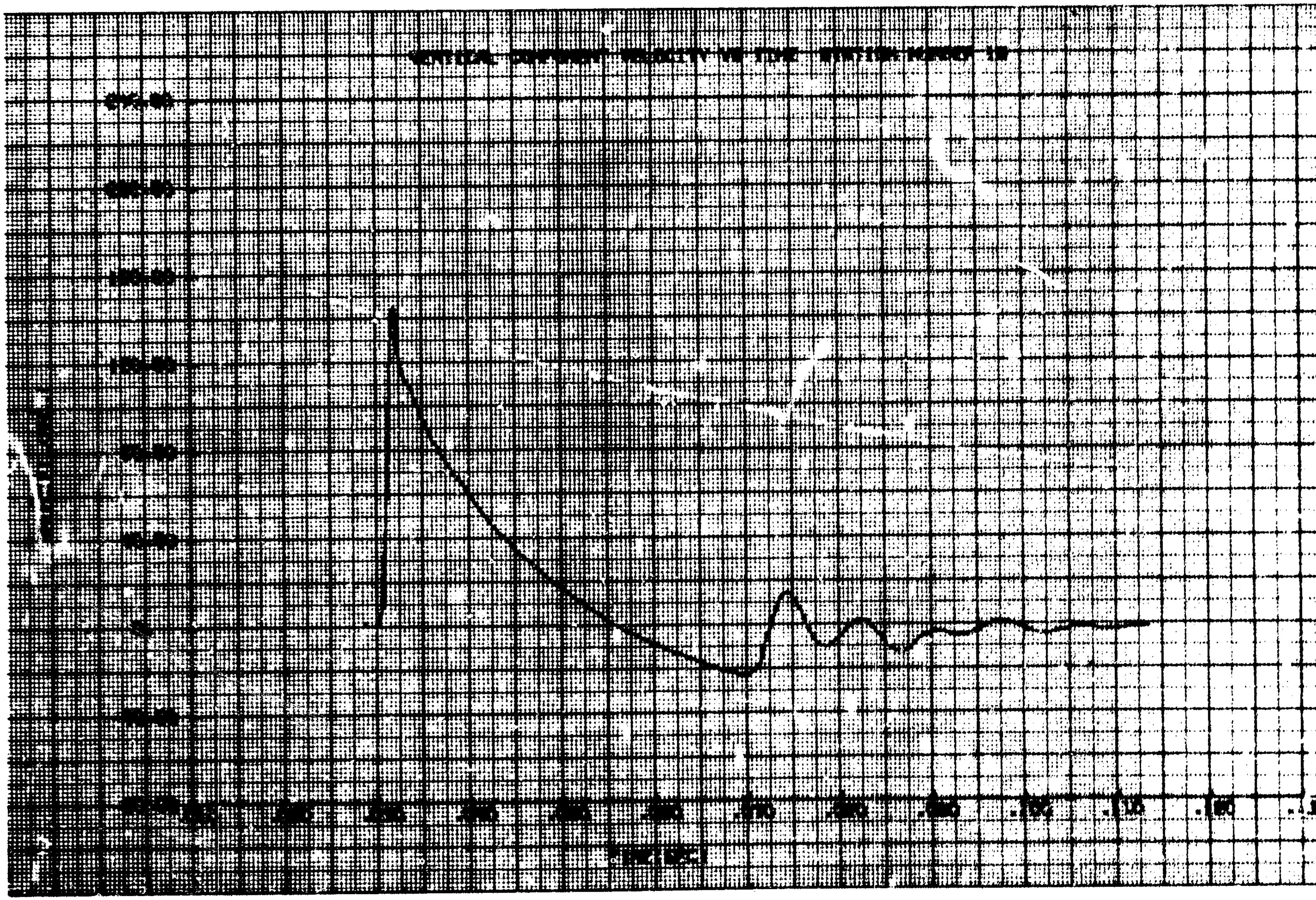

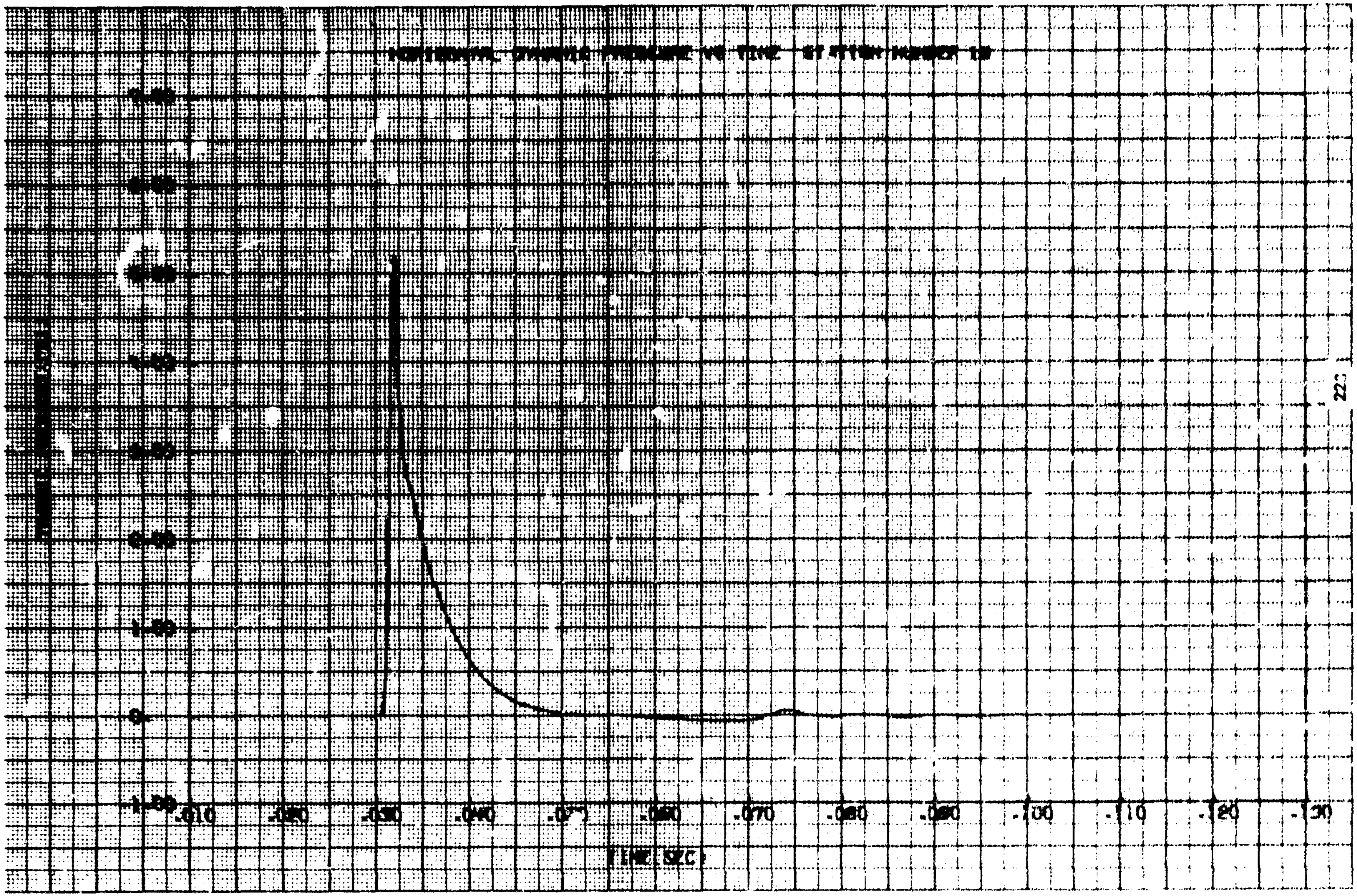
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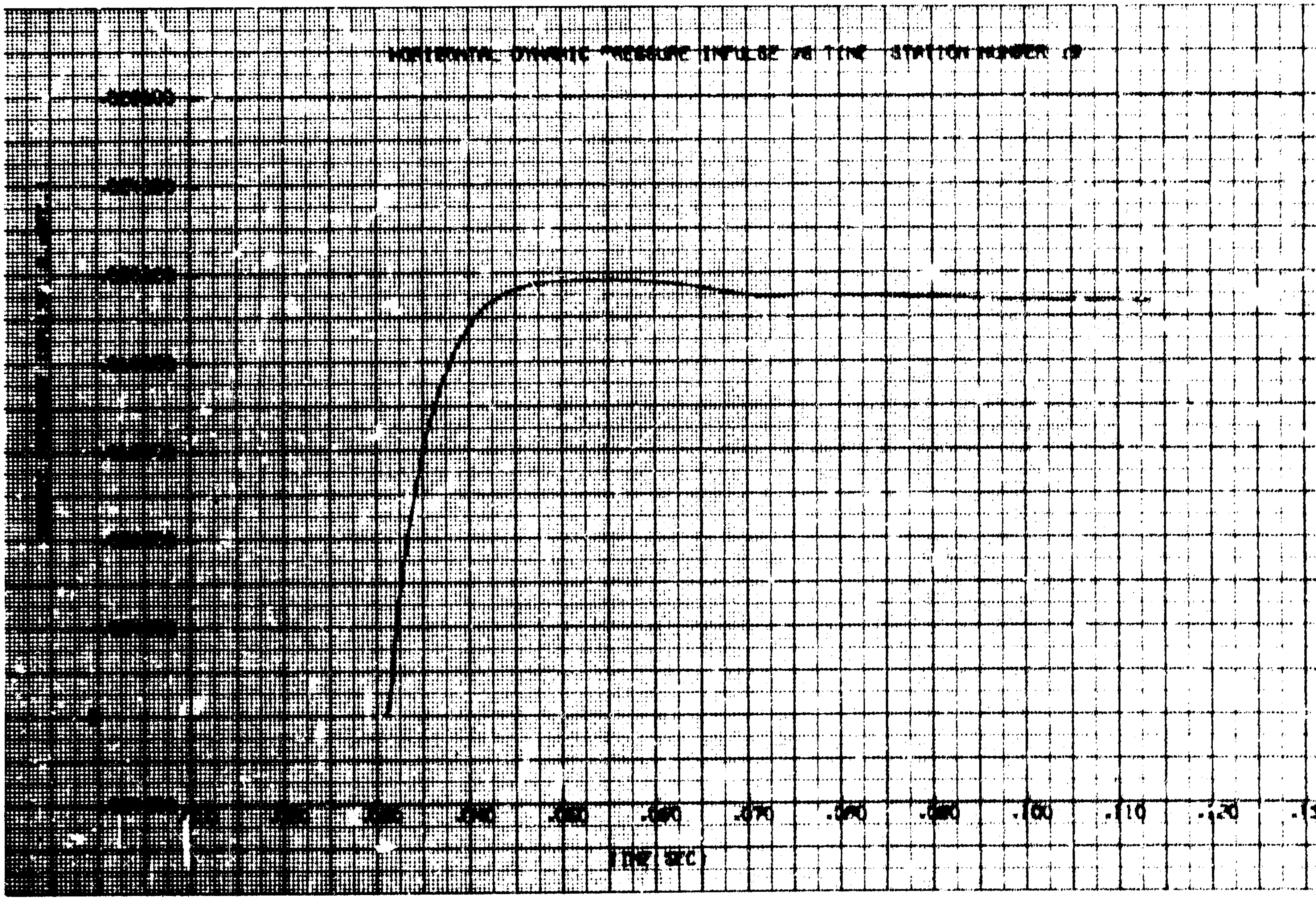
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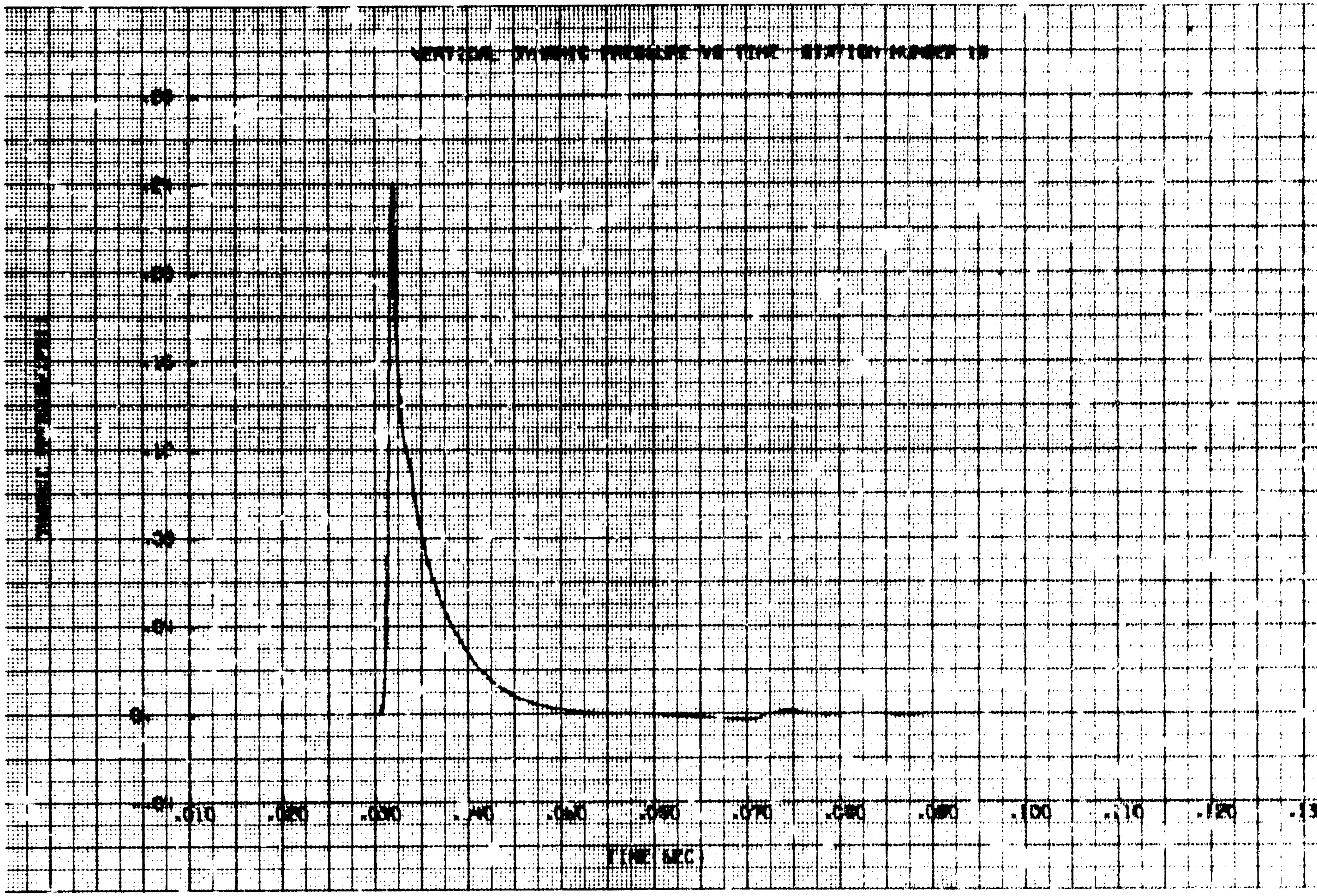
TIME (SEC)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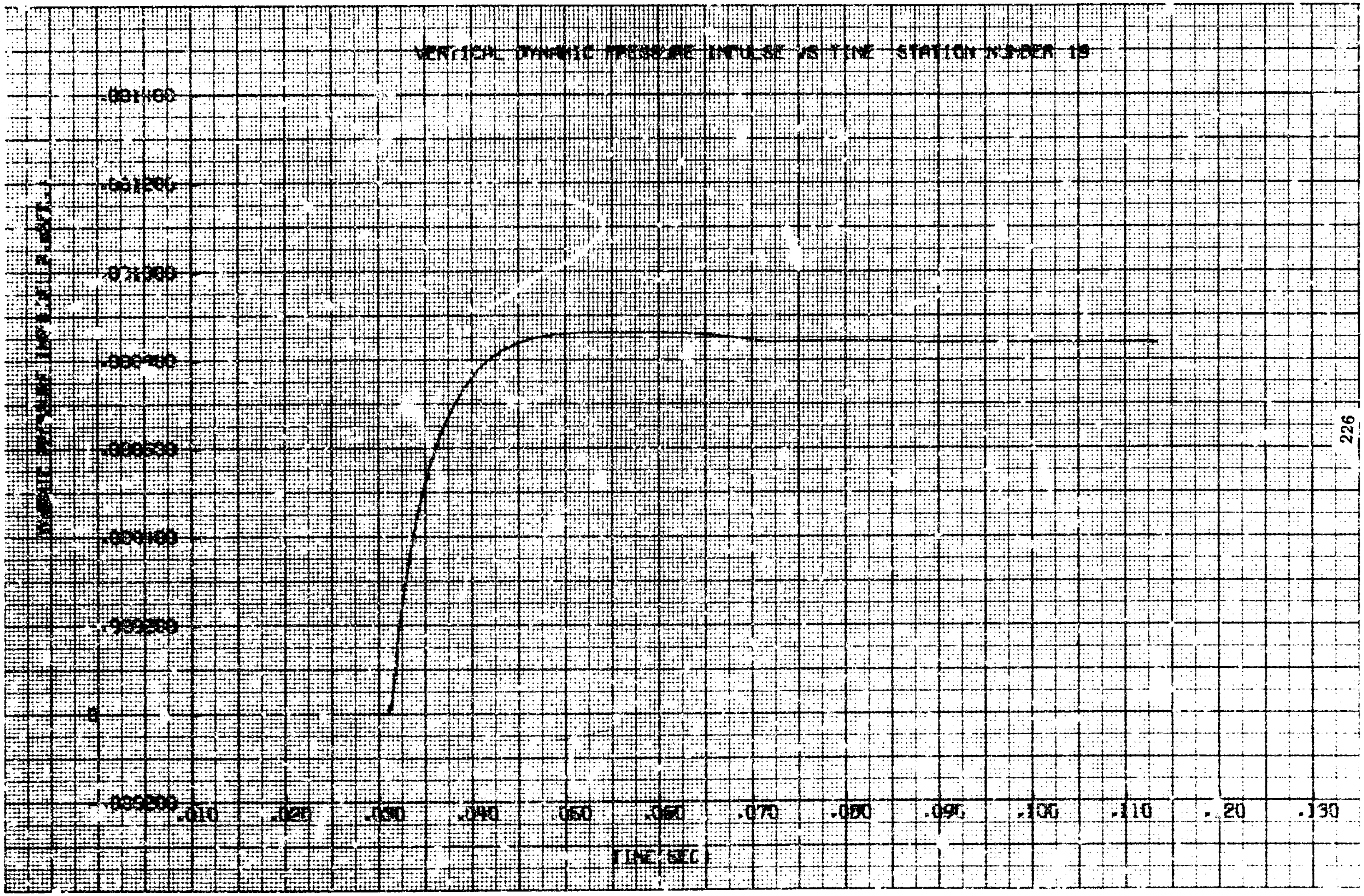
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TIME SEC

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

10 July 1966 to 10 September 1966

5. AUTHOR(S) (Last name, first name, initial)

Needham, Charles E.; Nawrocki, Edmund A., Capt, USAF; Whitaker, William A., Capt, USAF

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
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13. ABSTRACT

The results of a theoretical calculation of the detonation of 1,000 pounds of TNT (loading density 1.608 gms/cc) are presented. The charge was detonated 15 feet above ground with an ambient pressure of 12.6 psi and an ambient temperature of approximately 100°F. The calculation started with the burning of the TNT and was carried to 115 milliseconds. The calculation clearly shows Mach stem formation, triple point path, and flow field. The theoretical calculation agrees well with experimental data obtained from a test.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Blast Wave						
Shock Reflection						
Mach Reflecrion						
Triple Point						
TNT Detonation, Calculation of						
SAP Code						
SHELL Code						

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